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NOTES ON BUILDING CONSTRUCTION

PART II.

NOTES

ON

BUILDING CONSTRUCTION

ARRANGED TO MEET

THE REQUIREMENTS OF THE SYLLABUS

OF THE BOARD OF EDUCATION, SOUTH KENSINGTON

PART II.

WITH 496 ILLUSTRATIONS

New Edition, Revised and Enlarged

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PREFACE.

THESE Notes have been prepared primarily in order to assist students preparing for the examinations in Building Construction held annually under the direction of the Board of Education, South Kensington.

It is hoped that they may be found useful by others engaged in designing or erecting buildings.

The following Syllabus of the Board of Education has been taken as a Guide in the arrangement of the Notes, and in determining the subjects to be treated upon.

SYLLABUS.[1]

Subject III.—Building Construction and Drawing.

The instruction given should be so arranged that by the time the student finishes his course of study, he should have acquired a knowledge of building materials, plant, and construction sufficient for the work upon which he is likely to be engaged. That he may be able to make free use of this knowledge in practice, he must also be a good draughtsman; good drawing is an essential part of the course, but it must always be borne in mind that drawing is a *means* and not an end in itself; drawings of work to be carried out should be such as to give full information and exact guidance to workmen who may have to use them. In the higher stages of the subject students should acquire proficiency in making finished drawings as well as what may be called descriptive and explanatory drawings.

A larger number of questions will be set in the examination papers than the candidate will be allowed to attempt, so that he may have

[1] Taken from the "Syllabuses and Lists of Apparatus applicable to Schools and Classes other than Elementary," Board of Education, South Kensington. Edit. 1904.

some range of selection of questions which bear upon branches to which he has given special attention.

Compulsory questions may be set at the examinations.

It should be seen that candidates are fairly provided with pens, ink, pencils, and drawing instruments (including T and set squares, drawing boards, Indian ink, etc.) when they present themselves for the examination. The use in examination of the ordinary boxwood, ivory, or paper scales and protractors, and slide rules is permitted. Tables will be supplied to candidates in Stage 3 and Honours to assist them in calculation.

STAGE 1.

In Stage 1 the drawing exercises should not extend beyond descriptive and explanatory drawing, but they should aim at cultivating a fair degree of skill in pencil drawings. All lines should be neat and clear. Students who are quick in executing their pencil drawings should practise making ink tracings with clear lettering and figuring.

All students should practise freehand drawing of details, so that they may be able readily to make a neat dimensioned sketch from which a drawing to scale might afterwards be prepared or which may itself be sufficient for purposes of explanation. The use of squared paper may be introduced with advantage in exercises of this kind.

The Course of instruction should include elementary instruction, with reference to the various materials used in building. Each group of materials should be taken up in the class as introductory to a series of drawing exercises, illustrating their use in buildings so far as suitable for discussion in a first year's course. There would fall to be considered in this way :—

The nature and properties of sand, lime, and cement; the composition of mortar or concrete and its application in floors, walls, etc.; the properties of bricks, stones, tiles, and slates; the various kinds of timber in ordinary use; the constituents of cast iron, wrought iron, and steel, and the essential or characteristic differences of their properties.

Instruction should be given as to foundations in ordinary soils, footings for walls of moderate height; the construction of simple scaffolding; the various bonds of brickwork in plain walling, flues, arches, and fire-places; varieties of simple masonry such as rubble and ashlar walling and the plain masons' work on sills, reveals, etc.; plain carpentry in floor joists, stud partitions, ordinary roofs of span not exceeding that for a King Post truss; fineings of flats; simple joiners' work in floor laying, skirtings, deal-cased frames and double-hung sashes, and solid frames for simple casements, panelled doors and jamb linings, door frames and ledged and braced doors; ordinary plastering on walls, partitions, and ceilings, and the composition of the various coats; slating, including the dressing, cutting, and nailing

of the slates; plain tiling and pan tiling and the various methods of hanging the tiles, and the treatment of valleys, hips, ridges, and eaves; roof plumbing, including the laying of flats with rolls, drips, etc., lead gutters, and flashings. Students should also be taught how to draw the sections of rolled joists.

In all these subjects practical examples of the materials used and the various operations of dealing with them should be brought before the student, either in the class-room or elsewhere; in as many cases as possible, he ought actually to see and handle full-size examples of everything in which he is being instructed theoretically. He should also familiarise himself with the nature and use of all the tools used in elementary building operations. Students should lose no opportunity to inspect any building operations going on in their locality. Every student ought to examine in detail the structure of the houses in which he lives and works and attends classes.

STAGE 2.

Before proceeding to Stage 2, students should have a good knowledge of the subjects included in the Syllabus for a Preliminary Course for Trade Students as well as of those subjects included in the above Syllabus for Stage 1.

The Course of instruction in this stage should cover a more advanced knowledge of all the subjects enumerated for Stage 1, together with simple exercises in calculating quantities of materials, not such calculations as a Quantity Surveyor would make, but such as would fall to be made by a Foreman of Works who has to order sufficient materials for the amount of work which he knows has to be done.

The class lessons and drawing practice should include the following subjects: Excavation for trenches in various kinds of soils, including strutting and planking, concrete foundations for walls and piers, the use of damp courses and the materials employed for them; gauged brickwork; hollow walls and the various methods of binding them together; junctions of walls of various thicknesses and at different angles; chimney breasts and flues; irregular bonds; fireproof construction in walls and roofs; the best known building stones, their quarrying, bedding, cutting, and dressing; characteristics of timber, its conversion and seasoning. Attention should be given to the increasing use of machinery in treating timber for carpenters' and joiners' work; advanced carpentry and joinery; ordinary forms of staircase construction with close strings and bent strings; two- and three-light windows with cases, frames, and hung sashes, and also with solid frames, mullions and transoms and casements, outside doors with bolection mouldings, sash doors, and the finishings of door and window openings; furnishings in eaves, hips, ridges, etc.; the nature, qualities, and weights of various kinds of slates; elementary drainage; the laying and jointing of glazed stoneware pipes;

advanced constructional plumbers' work, including cold-water supply to cisterns, and the position of the same in a house; baths, sinks, water-closets and their connections, waste pipes, soil pipes, ventilation pipes, etc.; scaffolding for large buildings, shoring, strutting, needling, and under-pinning; the general principles of loaded beams; bending moments due to concentrated and distributed loads; the use of the triangle and polygon of forces in order to practically determine the resultant force in direction and magnitude, and to resolve such a resultant into its component forces; the determination of the stresses in simple braced structures; elementary exercises in the calculation of strength of materials.

STAGE 3.

The Course of instruction should include the consideration of buildings of all kinds and sizes. In the examination the candidate will be expected to show that he has a fair knowledge of the principles of Physical Science as illustrated in relation to building construction. He should be able to design simple roof trusses and beams, and to draw their stress diagrams; he should know the elements of the theory of arches, how to provide for the stresses in various parts of a building, and the methods of testing cement, timber, iron, and steel.

In the various sections of the Course exercises in calculating quantities of materials should be continued as in the preceding Stage.

The class lessons and drawing practice should include the consideration of :—

Foundations—natural and artificial, upon land and under water, damp sites and their treatment, Brickwork, including all kinds of bonding, setting out bond in frontages, etc.

Terra-cotta and artificial stone; their manufacture and uses.

Principles of sanitation; drains, traps, gulleys, disconnecting chambers, sewers, their ventilation and drain connections, iron drains. Drain testing and ventilation.

Masonry. Character of various stones used in building and localities where found, how to test for quality and bed, fitness of various stones for different atmospheres, weight generally, and approximate strength; stone stairs, composite walls, arches.

More detailed knowledge of scaffolding, including gantries, elaborate centring, framing for concrete walls and modern methods of hoisting materials, roofing up to 60 feet span. Timber: its seasoning, diseases, cause of decay, and means of preserving it. Roof timbering, open, hammer beam, and composite trusses. Modern iron trusses, including trussed purlins; all roof finishings, including slating, tiling, plumbing, etc., sky-lights and lanterns. Wood stairs of all kinds, including handrailing.

Cast iron, wrought iron and steel, properties, uses, strength, weight and preservation. Iron and steel columns, stancheons and girders, including riveting, bolting, etc.

Ventilation and heating; hot water supply; provisions for gas and electric supply, in so far as these may affect the structure of the building; water supply; lightning conductors; preservation of iron, timber, etc.; various kinds of glass and glazing; plastering in all its branches.

HONOURS.

No candidate will be credited with a success in Honours who has not obtained a previous success in Stage 3 (or Honours, Part I) and who does not qualify in the Board's examination in Architecture. The qualification in Architecture need not be obtained in the same year as that in the Honours Examination in Building Construction and Drawing.

The Examiners will have in mind in setting the questions the actual practice of architects in designing buildings, and in their guidance of assistants and clerks of works, to ensure that orders will be properly carried out, the dealing with contractors, and also the actual erections of buildings and carrying out of building operations. Candidates will be asked to make sketch designs and to give instructions to draughtsmen for careful scale drawings and specifications. The questions may deal with any part of the subject and with any kind of building, and may require a knowledge of any materials or construction in use in good practice.

Those candidates whose answering of the paper is sufficiently satisfactory, will be summoned to South Kensington or some other centre for a practical examination. This further examination will last for two or more days; the time will not exceed seven hours each day. Candidates will be asked to design a building suitable for a definite purpose, and they will be called upon to give such plans, elevations, and sections, and such details and notes for a specification, as shall be required by the Examiner. An estimate of cost may also be demanded.

Intimation concerning the general nature of the building to be designed will be sent in advance to candidates, together with the notice to attend for this second part of the examination.

For this practical examination candidates must provide T-squares, set squares, drawing instruments, ink, and colours. Drawing paper and drawing boards will be supplied by the Board of Education.

No candidate can be classed in honours who is not successful in the practical examination.

In these Notes the subjects of the above Syllabus are divided as follows:—

Parts I., II., and IV. treat on the majority of the subjects laid down as necessary for the examination in Stages 1, 2, and 3.

Part III. furnishes full particulars regarding the materials used in building and engineering works, including information on this subject that is required for Stage 3.

Part IV. explains and illustrates the problems involved in the theory of construction of buildings and their application in practice, and contains all that a student can require to prepare himself for the examinations on this subject for Stage 3. The history and styles of architecture, the preparation of specifications and quantities, the art of designing buildings from given conditions, and of freehand drawing and drawing to scale, must be studied in works specially devoted to those subjects.

REVISED AND ENLARGED EDITION, 1904.

The following are the principal additions or alterations that have been made in this edition :—

The subject of Joinery, which in former editions was treated partly in Part I. and partly in Part II., has now been brought together in consecutive order in one volume, so that the subject is complete within the scope of this Part.

Other subjects have, on the other hand, been transferred to Part I. in order to make their treatment consecutive in that volume, while four entirely new chapters on the important subjects of Drainage, Sanitary Fittings, Heating and Ventilation, and Electric and Gas Lighting (including also Bells and Signals, Telephones and Lightning Conductors) have been added to this Part.

NOTES ON BUILDING CONSTRUCTION

Note to Part II.

SEVERAL works on different subjects have been consulted in the preparation of these Notes, among which may be mentioned the following :—

- Adams' Designing Cast and Wrought Iron Structures.
- Dobson and Tarn's Guide to Measuring.
- Fairbairn's Application of Iron to Buildings.
- Hurst's Architectural Surveyor's Hand-Book.
- Latham's Sanitary Engineering.
- Latham's Wrought Iron Bridges.
- Laxton's Examples of Building Construction.
- Matheson's Works in Iron.
- Maynard's Bridges.
- Molesworth's Pocket-book of Engineering Formulæ.
- Newland's Carpenter's and Joiner's Assistant.
- Nicholson's Works.
- Pasley's Practical Architecture (Brickwork).
- Proceedings of the Institute of Civil Engineers.
- Proceedings of the Royal Institute of British Architects.
- Rankine's Civil Engineering.
- Reed on Iron Shipbuilding.
- Seddon's Builders' Work.
- Stoney on Strains.
- Thwaites' Factories, Workshops, and Warehouses.
- Transactions of the Society of Engineers.
- Tredgold's Carpentry (1870 edition); also a new, valuable, and greatly extended edition, by Mr. Hurst, C.E.
- Unwin's Wrought Iron Bridges and Roofs.
- Woodbury's Fire Protection of Mills.
- Wray's Application of Theory to the Practice of Construction (revised by Seddon).
- The Professional Journals.

The assistance derived from the above-mentioned works and others has been acknowledged, as far as possible, wherever they have been quoted or otherwise made use of.

Caution.—Some of the figures which appear to be isometrical projections are purposely distorted in order to bring important points into view.

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CHAPTER I.

FOUNDATIONS.

GENERAL REMARKS.—In this course the foundations likely to be required for ordinary buildings will alone be described, foundations under water, cofferdams, caissons, etc., being excluded, as appertaining more to engineering works than to ordinary building construction.

The great importance of a stable foundation will be apparent to every one, and need not be dilated upon.

Characteristics of a Good Foundation.—A good foundation should fulfil the following conditions:—

1. It must either be incompressible, or at least equally yielding throughout.

2. It should be perpendicular to the pressure upon it.

3. It should be of sufficient area to bear that pressure.

4. It should be unalterable in nature, either by atmospheric or other influences that it can possibly be subjected to.

Some natural soils fulfil these conditions, requiring only to be excavated to the proper levels; in other soils artificial means must be adopted in order to form a stable foundation.

Classification.—This has led to the classification of foundations under two general heads:—Natural Foundations, and Artificial Foundations.

The different kinds of soils have been arranged as follows[1]:—

1. *Incompressible soils,* such as rock, stony earth, and hard clay, which yields only to the pick or to blasting.

2. *Soils that are incompressible but require to be laterally confined to prevent them from spreading,* such as loose gravel and sand.

3. *Compressible soils,* such as ordinary clay, common earth, and marshy soils, some of which, such as clay and earth, are only compressible to a certain extent, while others are in an almost fluid state.

[1] Mahan's *Civil Engineering.*

Before proceeding to consider these in detail a few remarks may be made which are applicable to all foundations.

Preliminary Operations.—Before commencing a building, trial pits should be dug or borings made at different points on the site, in order to ascertain the nature of the ground, the thickness and inclination or "dip" of the strata; to find out whether water exists, and if so, at what level; also whether the ground has been mined or is full of dangerous fissures. If there be any springs on the site, their source should be ascertained and the water diverted.

The description of foundation having been decided upon, trenches must be dug to the widths and depths necessary, the bottoms of these carefully examined, sounded with a crowbar to ascertain any local defects, and then levelled throughout, in one plane if convenient, if not, in horizontal "benches" or terraces.

"Punning" or ramming the ground before commencing to build will sometimes produce a very considerable compression, and prevent a corresponding sinking of the building.

The ground should be well drained before digging the foundation, to increase its firmness; all bad parts should be cut out and made good with concrete, and loose portions rammed.

Surface water must be carried off by a catchwater drain, and "grips" or small trenches must be formed to carry off all water that may collect in the foundation during its formation.

As fast as walls are built up they should be "punned" (that is, filled in and rammed) on each side.

On benched foundations care must be taken in rising from the lower to the higher level (A to B, Fig. 1) to have large stones with well-dressed beds and the joints as few and as thin as possible, otherwise the unequal settlement caused by the number of joints in A C being greater than that in E F will lead to fracture.

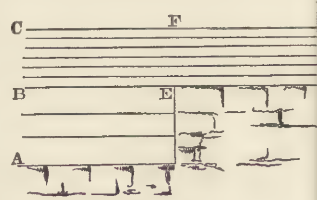


Fig. 1.

In such a case the masonry should be left thoroughly to set before being built upon.

The foundations of the angles of a building should be laid with large and heavy stones, and great care should be taken that the foundations under the higher walls are not liable to consolidate more than those under the lower walls, otherwise where these are connected fractures will appear.

All foundations should be at such a depth as to be out of danger from the effects of frost.

In England a depth of 3 feet will generally be sufficient to ensure this, but in clay soils a depth of 4 feet will be necessary, as they are frequently laid open to injury by fissures formed by heat.

Permanent drains should be laid so as to keep all foundations constantly dry; water is their great enemy, causing swelling, removal and subsidence of the soil, expansion from frost, perpetual damp, etc.—even in some kinds of rock it percolates between the masses and loosens them, so that when pressure comes upon them they sink.

Incompressible Soils.—Rock.—Solid rock under the *whole* of the building affords a first-rate foundation if it is perfectly uniform in character, thick enough to bear the weight safely, with an upper bed approximately horizontal or perpendicular to the pressure upon it, and not liable to be affected by atmospheric influences.

In such a case it will be necessary only to break down projecting points, cut away loose and rotten parts, making good and carefully filling in all cavities with concrete.

If the strata are inclined there is danger of the upper layers sliding over the lower, and also expense in "benching" or levelling in steps.

Again, if the rock is (like some clay slates, for example) of a nature to disintegrate when exposed to the weather, it should be protected by a bed of concrete.

The foundation should be so arranged that the pressure upon the rock does not exceed one-eighth of that necessary to crush it.

Partly Hard and partly Soft Ground.—A foundation consisting partly of rock and partly of some softer stratum is most dangerous and untrustworthy, as the latter will yield more than the former, causing unequal settlement and fracture of the superstructure.

If the softer parts are of small extent they may be arched over, using the adjacent portions of rock as abutments.

If this be not possible they should be consolidated by driving in piles close together (see page 8), or excavating to a good depth and filling in with concrete.

If neither of these expedients can be adopted the building over the soft parts should first be carried up and allowed to settle to

its bearings, and then the remainder built upon the hard rock, the latter being kept distinct from the former.

GRAVEL, when sound, makes one of the best possible foundations, as it is incompressible, and not affected by atmospheric influences.

If loose and coarse it may be greatly improved by grouting it with thin mortar, or sometimes a thin layer of concrete is spread on the bottom of the trench.

If very unsound it may be necessary to proceed as in the case of loose sand (see below).

CHALK varies immensely in its nature and characteristics; sometimes it is found as hard as rock, in other cases as soft as butter.

The hardest description of chalk may be treated as rock if its permanent dryness can be ensured.

The softness of chalk is caused by wet; before using it as a foundation all water should be removed and prevented from recurring.

This may be done by draining the trench, punning the sides with clay to prevent the ingress of water, or by putting in concrete at weak points.

Springs should, however, rather be diverted than dammed out, as otherwise they will very likely burst through in rainy weather.

CLAY is a good soil to build upon when it is sound, tolerably dry, and protected from the action of the atmosphere by making the foundations deep or covering the bottom of the trenches with concrete.

Clay is very liable, especially in hot weather, to crack and form deep fissures, by which water is led below the surface, which will injure the footings unless they are placed deep enough to be out of the reach of the fissures and well drained.

When these precautions are neglected the clay undergoes continual changes in bulk from atmospheric influence, and becomes a very dangerous material to build upon.

Soils requiring Lateral Confinement.—SAND forms a capital foundation to build upon as long as it is prevented from escaping laterally by sheet piling (see page 8) or other means.

QUICKSAND AND SILT.—The same remark applies to these, which are the most treacherous of all soils, and will, unless such precautions are taken, yield or slip under the slightest weight.

In these soils, as also in very loose gravel, care must be taken

to exclude water, which might otherwise penetrate and wash away the soil, causing hollows in the foundation and subsidence in the superstructure.

Compressible Soils.—Foundations in these soils require great care, more especially if the site is made up of different kinds, one more compressible than the other; in such a case unequal settlement may be apprehended, and should be guarded against.

Ordinary Earth or Soft Clay.—In these it will be sufficient to dig a trench considerably wider than the thickness of the wall and deep enough to be below the action of frost, and to fill it with concrete.

The pressure is thus distributed by the concrete bed over a larger area, and does not bear so heavily on each superficial foot of the soil.

Very Soft Soils.—When the ground is marshy or of such a nature that it would not bear the weight required, even when distributed over a large area of concrete, more complicated arrangements must be adopted, according to the nature of the case.

1. *A soft stratum of moderate depth overlying hard ground.*

In this case the foundation should be carried down to the solid ground; or, if this would be too expensive, a number of piers may be sunk, and arches turned from one to the other, upon which the building may rest, or similar piers may be used to support a timber platform; or again, instead of the piers, holes may be driven through the soft upper stratum and filled in with concrete, sand (if the ground will resist its lateral pressure), stones, or other incompressible material; or lastly, piles may be driven into the hard substratum to act as supports for a platform.

2. *Ground very soft to an indefinite depth.*

Such ground may be treated in several different ways.

Sometimes a wide trench filled with good concrete, of such a thickness as to resist fracture, will answer by distributing the pressure over such a large area that the soil is enabled to bear it, or a trench may be filled with moist sand carefully punned; in this case the natural soil must be able to retain the sand laterally, as it will press upon the sides as well as the bottom of the trench.

If the trench cannot be kept free from water, holes about 6 feet deep and 6 inches in diameter may be bored and filled with slightly moistened sand. These are better than timber piles, as the sand transmits the pressure upon it tolerably well, and driving is avoided, which shakes the ground.

Another plan is to form a raft of timber or fascines, which floats upon the nearly liquid soil and distributes the weight of the building over a large area.

In such a case it is important that the centre of gravity of the building should be immediately over that of the platform, and the latter should be evenly weighted, or it may sink more on one side than on the other.

A timber platform is constructed by placing short lengths of timber across the foundations; these are tied longitudinally by long planks laid to the width of the bottom course of masonry.

A fascine platform consists simply of two or three courses formed of fascines (long bundles of brushwood) laid close together, the alternate courses being in opposite directions, and the whole being kept in position by wooden pickets.

Such platforms should either be at a depth where they will be constantly wet, or be so drained as to be permanently dry, otherwise the material will soon perish.

Again, a soft soil may be consolidated by driving into it, over an area larger than the proposed building, short piles quite close together; these are prevented from sinking by the friction of their sides against the soil.

On the heads of these piles may be formed a platform consisting either of timber, a bed of clay, or a layer of concrete.

In all these cases the pressure has a tendency to cause the ground immediately around the foundations to rise; this must be counteracted by placing stones or concrete upon it so as to act as a counterbalancing weight.

Sometimes before laying the platform the site is surrounded by sheet piling to prevent the lateral escape of the soft soil when the weight of the building comes upon it.

3. *A crust of good ground overlying a soft substratum.*

If the crust be thick enough to bear the weight required it should be left alone, care being taken not to cut or injure it.

In alluvial soils there is frequently a layer of clay over a stratum of soft mud; in such a case piles would do harm, as they would disturb and injure the crust of clay; it would be better, therefore, merely to pun and consolidate the clay with a rammer.

The upper crust should be sounded by striking it with a log; experience will tell whether it gives out a clear ring or a hollow sound; in the latter case it is not to be trusted.

When the upper crust is not thick enough to bear the weight originally intended, the area of the foundations may sometimes be increased so as to reduce the pressure, on each superficial foot, to what the crust can bear.

When the substratum is sand it will be safe to build upon if its lateral escape is prevented. A peaty substratum should, if possible, be thoroughly drained.

When the hard crust rests upon a soft stratum which crops out on a cliff or the bank of a river, particular care must be taken or it will be found to ooze out and cause a subsidence of the crust.

When the soft substratum is very shallow, open drains may be cut so as to encourage it to ooze out and permit the weighted crust to take its bearings; but if it be of considerable depth such excavations must be carefully avoided.

Concrete Foundations.—The composition, characteristics, and method of making and laying concrete are given in Part III.

The great use of concrete for foundations is generally to form a solid base or platform, which will cause the weight of the building to be distributed over a larger area, and thus reduce the pressure on each superficial foot to whatever the soil is able to bear.

To ensure the stability of the bed of concrete itself it must be composed of such materials, and be of such a thickness, that in case of the subsoil yielding it will settle uniformly in one mass, and bear the cross strain upon it without breaking; care should also be taken that its composition is such that it is in no danger of crushing under the weight brought upon it.

The various cases in which concrete is useful have been considered in the preceding sections.

Piles and Pile Foundations.—TIMBER PILES may be made of elm, larch, fir, beech, oak, teak, or greenheart.

The straightest-grained timber should be selected, the bark removed, and any rough projections smoothed off; all large knots should be avoided, and diagonal knots especially are a source of danger, as a pile is very likely to be broken off at the point where they occur.

Piles should, if possible, be of whole timbers, and driven with the butt, or natural lower end, downwards.

The head of the pile should be bound round with a wrought-iron hoop to prevent it splitting when driven.

The lower end should be pointed, and if it has to encounter stony or hard ground should be shod with iron.

Fig. 2 shows an ordinary form of wrought-iron shoe, and Fig. 3 an improved form, in which the lower portion C is of cast-iron, forming a good wide abutment for the timber, which tends to prevent the danger of its being crushed as the pile is driven. The wrought-iron pins, *a a*, are cast into the portion C, and their heads hammered out like a rivet to secure the straps *s s*.

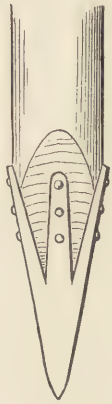


Fig. 2.

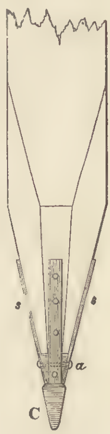


Fig. 3.

From the remarks at pages 4-6 it will be seen that piles are used for foundations in three different ways. They receive distinctive names, and their forms and dimensions are governed accordingly.

Bearing Piles are driven down either until they reach a hard stratum, or until the friction on their sides prevents them from sinking, upon which they are used as pillars to support a platform of timber.

Such piles, if of wood, should be whole timbers from 9 to 18 inches in diameter, and if they are in soft soil their length should never be more than about twenty times their diameter, or there will be danger of their bending when driven.

Short Piles are driven into soft soil to compress and consolidate it. Upon their heads may be placed a platform of timber or layer of clay or concrete.

These piles are only from 6 to 12 feet long—of round timber about 6 inches in diameter. They should be driven as close together as is possible without the driving of one pile causing the others to rise; to prevent this, it is found necessary to place them at intervals of about 2 feet 6 inches from centre to centre.

Sheeting Piles are used to enclose the areas of a foundation, and thus prevent the soil from spreading laterally, or to protect it from the action of water.

Sheet piles are flat planks, varying in width, and from 3 to 10 inches thick. They are sometimes grooved and tongued down their edges so as to form a tight joint, and sharpened to an edge at the lower end which may be shod with iron.

In using sheet piling to enclose soft ground long "guide piles," about 6 to 10 feet apart, are first driven in the direction required.

On opposite sides of these are fixed beams ("string pieces" or "wales") at a horizontal distance apart just equal to the thickness of the sheet piles, which are driven down between them, commencing at the guide piles, and working inwards in each bay, so that the last sheet pile driven acts as a wedge and tightens up the whole.

PILE FOUNDATIONS.—*Platform on Piles.*—After the piles are driven, and their heads sawn off level, a timber platform is generally laid upon them.

This consists of heavy square balks, called string pieces and cross pieces, notched into one another so as to form a grating or "grillage." The string pieces are notched over the heads of the piles, and secured to them by trenails.

The ground between the piles is often taken out to a depth of 3 or 4 feet, and the space filled with concrete. The intervals between the timbers of the platform are sometimes similarly filled in, and in some cases a bed of concrete is substituted for the platform altogether.

Fig. 4 is an illustration of a portion of pile foundation for a thick wall. P P P are the piles (shod in different ways), S S the string pieces, and C C the cross pieces. The platform Y Y is composed of Yorkshire landings 6 inches thick.

A portion of the foundation is secured by sheet piling, S P, driven between the waling, W, and the outer cross piece of the grillage.

A disadvantage in the string pieces and cross pieces is that the heads of the piles, bearing upon their sides, bend and crush into the longitudinal fibres, indenting the timber, and causing it to sink down upon the pile heads. Where there is a really good strong bed of concrete the string and cross pieces can, with advantage, be omitted; in fact, in many cases a good broad and deep bed of solid concrete enables the use of the piles themselves to be dispensed with altogether.

CAUSES OF FAILURE OF PILE FOUNDATIONS.—Pile foundations are liable to fail, from the softness of the ground being such that it does not offer sufficient resistance to a lateral movement, in consequence of which the piles lose their original position, and the wall has a tendency to upset.

Wooden piles are sure to be destroyed by rot in any position where they are alternately wet and dry.

If used in sea water they are liable to attacks from worms, by

which they are soon destroyed. These attacks can best be delayed by completely charging the pores of the timber with creosote (see Part III.), or they may be prevented for a time by covering the surface of the timber with scupper nails driven close

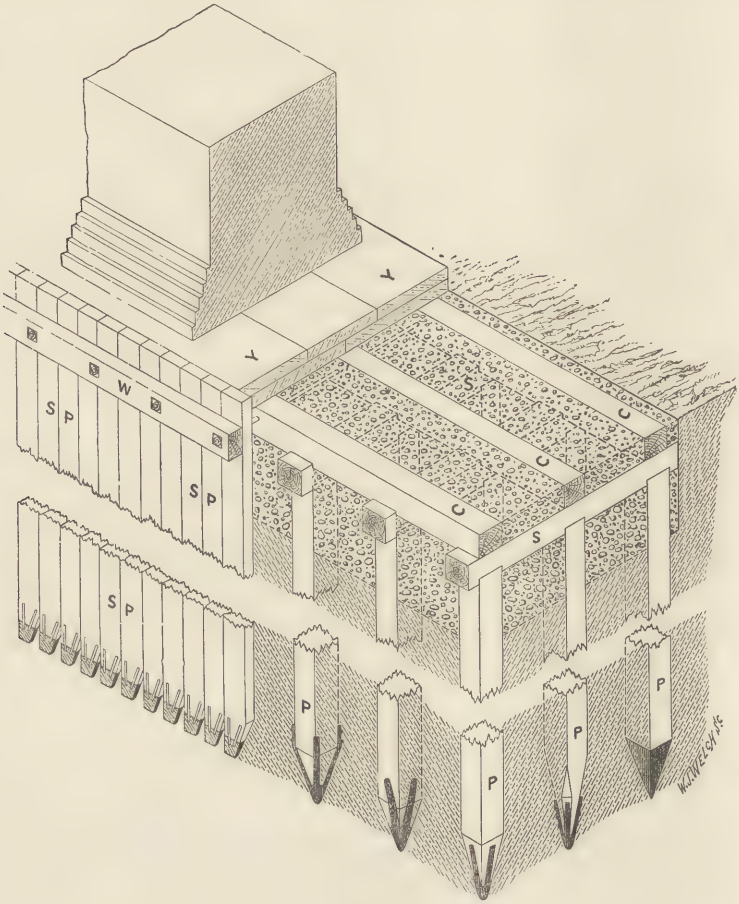


Fig. 4.

together, or, at a great cost, by sheathing the pile with copper. After a time, however, the worm manages to get under the nails or sheathing, and to eat the wood completely away, leaving an apparently sound but entirely hollowed pile. (For an account of the worms, etc., see Part III.)

Partial piling provided under a portion only of a wall is most

dangerous, as it leads to unequal settlement, by which the wall may be fractured.

In a wall with buttresses the unequal weight on the piles has led to failure.

Iron Piles have been introduced to avoid the natural defects of those made of timber.

Cast-iron Piles have been used of various cross sections, such as square, round, hollow, and cross shaped.

In driving them a block of wood or "dolly" must be interposed between them and the monkey, for fear of breaking the pile by the sudden shock.

They have a disadvantage for the foundations of buildings, inasmuch as they cannot be cut off to a level at the top.

Cast-iron sheet piling has been extensively used; it consists generally of flat plates, stiffened by vertical ribs, and furnished with overlapping edges. The guide piles may be of the same construction, square or semicircular in cross section.

Screw Piles.—In these the pile itself may be of timber, or a cylinder of cast or wrought iron.

It is furnished at the lower end with a short and broad cast-iron screw blade, which is twisted (Fig. 5) round under pressure so that it enters the ground, from which a great force would be required to withdraw it.

Fig. 5.

The best way of driving these piles is by attaching long radiating levers to the upper end, and turning them round by means of animals moving on a temporary platform.

Tubular Foundations.—These are generally composed of cast-iron tubes of large diameter united in lengths by internal flanges and bolts.

These cylinders are sunk by excavating the earth from within and under them in various ways. The water may be kept out of them by pumping in compressed air. The excavation can then be done by men working within the cylinder, or if the water is not forced out the excavation may be carried on by tools, or special excavating machines lowered from above. In cases where the soil is very soft, cylinders have been sunk by exhausting the air from within them, so that they are forced down by the atmospheric pressure acting upon their covers or upper surface.

Iron piles and tubes are more in use for the foundations of

engineering works than for ordinary buildings; they need not therefore be further noticed in this course.

Well Foundations.—With these the building rests upon a number of hollow cylinders, or wells, of brickwork, concrete, or masonry, which form supports in the same way as hollow piles or tubular foundations.

The masonry is first built to a height of about 4 feet upon a wooden curb or frame of the size of the work; this is then undermined and allowed to sink its full depth into the ground; another 3 or 4 feet is then added, the structure is again undermined, and so on until the required depth has been attained.

The masonry must be of first-rate quality, and the undermining must be equal all round, or the work will be strained and crack.

Well foundations are extensively used for ordinary buildings in India; but in this country they have been restricted to cases in which a support is required for heavy wharf walls and other structures.

Pile Engines of various kinds are used for driving piles into the ground.

In all of them a heavy block of iron or wood called a "ram" or "monkey" is raised by a rope or chain over a pulley to the top of an upright frame and then allowed to fall suddenly upon the head of the pile, being guided in its descent by arrangements which vary considerably in different engines.

There is some difference of opinion as to whether piles are best driven by blows slowly delivered by a heavy monkey falling through a considerable height, or by a light monkey, with a short fall, delivering blows in quick succession. The latter plan is, however, in nearly every case by far the best, as the heavy blows crush the foot of the pile just above the shoe, convert it into a large mass or ball of fibres, which prevents it from penetrating further.

Ringing Engines.—In these the chain or rope attached to the monkey, after passing over the pulley at the head of the frame, is connected with several short ropes, each of which is hauled on by a man until the monkey has been raised 3 or 4 feet, when upon a given signal the whole are let go at the same moment so as suddenly to release the monkey, which falls upon the pile.

Immediately after the blow is delivered the men pull the rope so as to tighten it and take advantage of the rebound of the monkey from the head of the pile.

Fig. 6 shows a very simple form of ringing engine adapted for use by seven or eight men.

The frame consists merely of an upright pole or leader supported by two side braces, and steadied by guys secured to an iron strap at the head.

The monkey, M, here shown is of cast-iron, weighing from 250

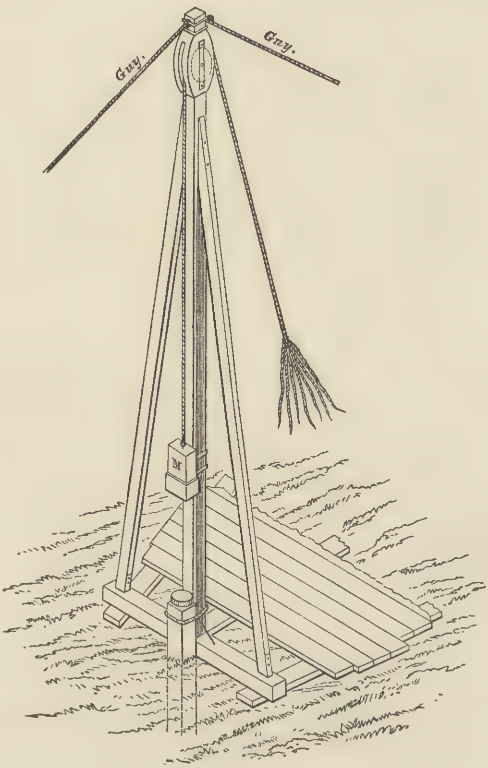


Fig. 6.

to 300 lb., and is guided in its descent by wrought-iron straps fixed to its sides, which embrace the "leader," and are secured at the back by a transverse bar passing through slits formed in the ends of the straps.

The rope shown round the head of the pile is intended to keep it close up to the engine so that it may not get out of place while it is being driven.

This engine is generally used for small piles; it delivers its

blows with great rapidity, the monkey being raised only as far as the men can reach, some 3 or 4 feet each time, and the rope never being detached from it.

In some forms of this engine a monkey weighing from 600 to 800 lb. is used.

In these a stronger and more elaborate framing is required. Two parallel leaders are generally made use of, connected by a cross head, and further supported by framing.

In such engines the monkey may be provided with ears and projections cast on its sides, which travel in grooves formed on the inner sides of the leaders and thus guide the monkey during its fall.

Professor Rankine recommends that the men to work such an engine should be in the proportion of 1 to every 40 lbs. weight in the monkey, and states that they work most effectively when after every three or four minutes of exertion they have an interval of rest, and that under these circumstances they can give about 4000 or 5000 blows per day.

Crab Engines are similar to the last described in their general arrangements, but the framing is much higher and the monkey is lifted to a height of 10 or 12 feet by means of a windlass or crab worked by men, horses, or steam-power.

In the commonest form the monkey is raised upon a hook, *h* (Fig. 7), attached to a counter-weighted lever, *l*, to the long arm of which is attached a rope, by pulling which the hook is pulled out and the monkey is permitted to fall.

The monkey can be released at any height by pulling the trigger rope C.

It is generally desirable that the height of fall should be the same for each stroke; this may be ensured by attaching the trigger-rope to the head of the pile.

Sometimes the rope is tied below, to the framing of the pile-driver, so as to cause the release of the monkey always at the same point, but in this case the height through which the monkey falls of course increases as the pile is driven further down.

The monkey should always descend in a line parallel to the direction of the pile. When that is vertical the guides are in the uprights of the framing, but if the pile is to be driven in an inclined position the guides must be similarly inclined, or if the framing will not permit this, temporary guiding pieces must be fixed at the required inclination.

Steam Pile-Drivers are those in which a small steam engine takes the place of the manual power applied to the crab. There

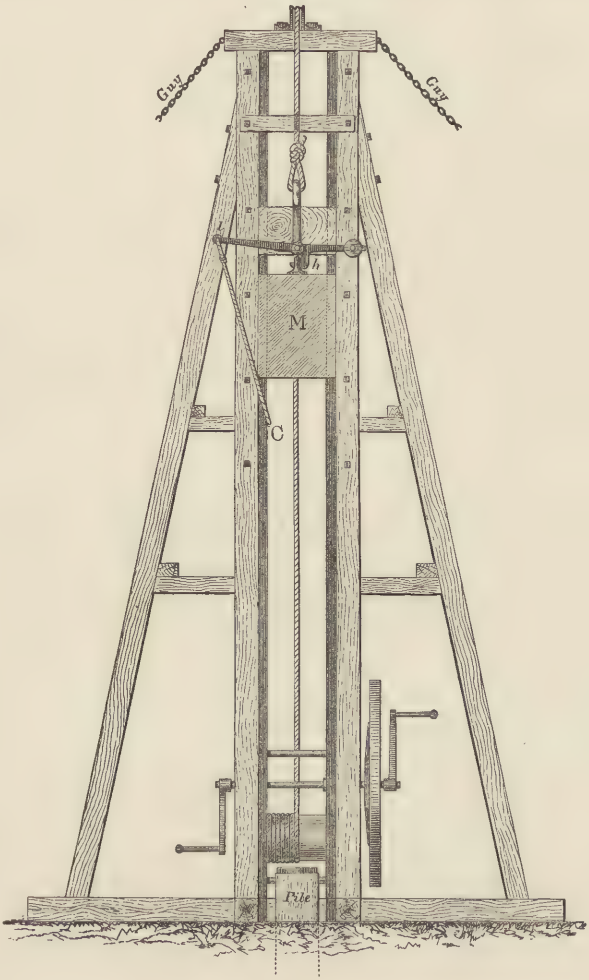


Fig. 7.

are several forms of steam pile-drivers, but it is unnecessary to describe them in these Notes.

A "*Punch*," or "*Dolly*," is a short post or block interposed between the head of the pile and the monkey, either when the former would otherwise be out of reach, or when it is advisable, as in the case of cast-iron piles, to deaden the blow.

"According to some of the best authorities the test of a pile's having been sufficiently driven is that it shall not be driven more than $\frac{1}{5}$ inch by 30 blows of a ram weighing 800 lb. and falling 5 feet at each blow.

"It appears from practical examples that the limits of the safe load on piles are as follows:—

"In piles driven till they reach the firm ground, 1000 lb. per square inch of area of head.

"In piles standing in soft ground by friction, 200 lb. per square inch of area of head."—Rankine.

Drawing Piles.—This may be necessary when a pile breaks, or for other reasons.

It is generally effected by fastening the head of the pile to a long beam and using the latter as a lever, or it may be done by means of the hydraulic press.

A pile may also be drawn by means of a large screw, one end of which is fastened to the head of the pile while the other passes through a cross head temporarily but firmly supported above it.

Inverted Arches are used for distributing uniformly over a foundation the pressure of a building, which in some cases would otherwise come only upon a few points.

For instance it is evident that in the building shown in Fig. 8 there would, in the absence of the inverted arches, be a great pressure upon the foundation immediately under the abut-

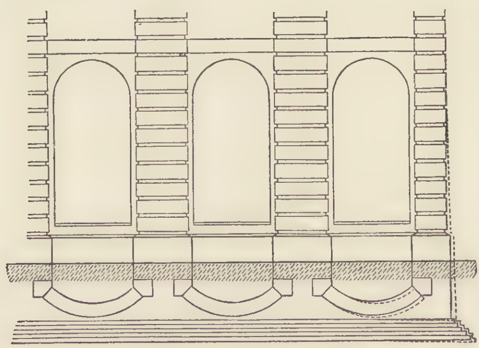


Fig. 8.

ments and piers, but none at all on the portions under the voids; the arches, however, cause the weight to be uniformly distributed over the whole.

Such arches are of course only necessary when the foundation is of a compressible nature.

Arches of 9 inches in thickness are sufficient for ordinary pur-

poses, but for large and heavy buildings they may be increased in thickness; the angle subtended by the arch should not be less than 45°.

It is most important that inverted arches should have an efficient abutment on both sides; if not, they may do more harm than good by thrusting out the corner of the wall as shown in dotted lines in Fig. 8.

When a chasm or bad soft place occurs in a foundation immediately under a pier and cannot be filled up, it may be bridged over by an ordinary arch whose extremities spring from or rest upon those of the inverted arches which lie under the openings on either side; or, where there are no inverted arches, the ordinary arch may spring from the sides of the chasm.

Chapter II.

EXCAVATIONS, SHORING, SCAFFOLDING.

EXCAVATION.

IN clearing and levelling the site for buildings very large quantities of earth may have to be removed from one spot to another, for which special arrangements would be necessary. Such arrangements, however, are rather beyond the province of these Notes, in which it is proposed to consider only the excavations required for the foundations of buildings to be placed upon a site which requires no special preparation in the way of levelling.

In all excavations for foundations the solid ground at the bottom of the trenches should be left to the required levels—not made up with loose earth—and temporary drains should be cut to carry off the rain that may fall during the progress of the work.

In excavating trenches for brick or stone footings an extra width of about 6 inches on each side is generally allowed at the bottom of the trench to give the men room to build; but, when concrete is to be used the excavations should be of the exact width required for the bed of concrete itself.

SHORING AND STRUTTING.

When trenches have to be dug in loose ground it is necessary to support the sides of the excavation by timbering and shoring.

In moderately firm ground, after a depth of 3 or 4 feet has been excavated, a few rough planks or "*poling boards*" P P (Fig. 9) are placed at intervals varying with the nature of the soil against the sides of the trench, and kept up by jamming or wedging in between them struts (S) of rough scantling from 4 to 6 inches square.

In looser ground it is necessary to place the poling boards

closer together, and so support them (Fig. 10) by 3-inch planks W W called "walings." The struts must be made thick, in pro-

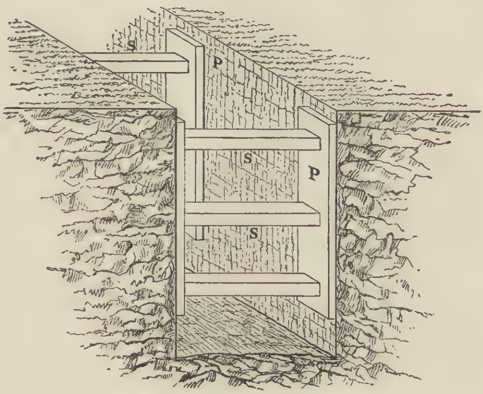


Fig. 9.

portion to the width of the trench and the pressure upon them, and their distance apart will depend upon the strength of the walings and the nature of the soil.

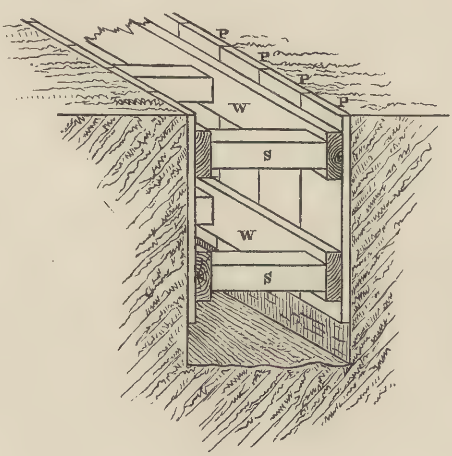


Fig. 10.

The poling boards P P are often in short lengths of about 3 feet, so that no greater depth has to be excavated before they can be inserted.

In very loose soils, such as running sands or slipping clays, it is evident that the sides would fall in if an attempt was made

to excavate the trenches to a depth of 3 or 4 feet before supporting them (Fig. 11).

To prevent this the poling boards are sometimes put in horizontally—as "*sheeting*"—one at a time. A portion 9 inches or a foot deep is excavated, and at once supported by planks placed longitudinally on both sides and kept apart by struts, then another depth of 9 inches is taken out and another plank placed on each side below those already in position, and these last also strutted. When five or six planks have been thus inserted on each side walings may be added, and some of the struts dispensed with.

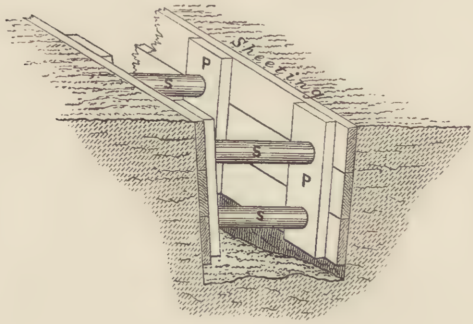


Fig. 11.

The timber used for shoring important excavations should be hard and tough—seasoned,—barked before use—so placed as to receive the stress on its end grain, and as large a bearing surface as possible should be allowed, especially when the end of one timber bears upon the side of another.

All shores should be driven from above, not sideways or horizontally. The planks or walings at the sides of an excavation should be at a slight inclination, as in Fig. 11, the upper edge sloping toward the earth they support, so that when the shore, whose ends are cut to the proper angle, is driven down from above, it will take a fair bearing.[1]

Fig. 11 shows round shores, which are sometimes made by cutting up old fir scaffold-poles. Half-round walings are also often used.

Sometimes in very bad soil long planks called "runners," having sharp ends shod with iron, are substituted for the poling boards; these are driven in as the trench is dug, their points being kept a foot or so below the bottom of the portion excavated.

In very deep excavations platforms are required at vertical intervals of about 5 feet to receive the earth thrown up by the men from stage to stage.

[1] *Transactions*, Society of Engineers, 1873.

In this case these stages may rest upon the struts of the timbering, which should be made particularly firm to ensure safety

Shoring Buildings.

It is frequently necessary to afford buildings temporary support in consequence of the instability of the walling, caused either by the removal of adjacent houses, by faults in construction, or by defective foundations.

Inclined Shores.—This support is obtained by propping up such walls as are likely to be unstable with balks of timber called "shores."

Shores may be used singly, as shown at A, Fig. 12, or arranged in groups of two or three, according to the height of the wall to be supported.

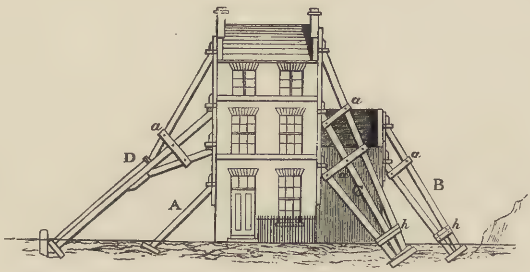


Fig. 12.

The arrangement at B is a double shore adapted for walls of moderate height. Three shores are used at C, where the wall is higher.

Another combination of those shores, shown at D, is adapted for cases in which long timbers are scarce.

In all these cases the shores are placed in an inclined position, their feet are fixed firmly on the ground—or, if that be soft, are made to abut on blocks or thick planks called "footing pieces," buried in the ground; these distribute the pressure, and prevent the shore from being forced into the soil.

When two or three shores are combined they are secured together by means of cross pieces of plank, *a a*, nailed on each side of the balks; the feet are strongly bound together with hoop iron, *h h*.

The upper end of the shore abuts against a thick plank placed

against the wall extending over the height required to be supported, and secured as follows (see Fig. 13):—

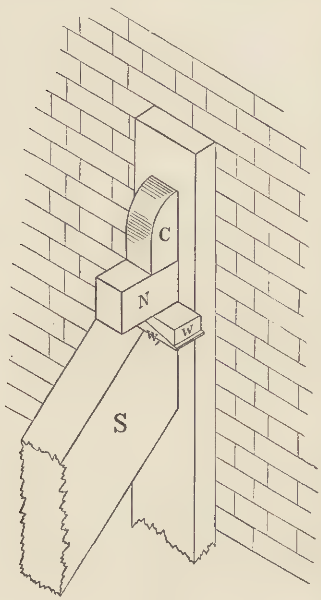


Fig. 13.

Holes from 4 to 6 inches square are cut through the plank and into the wall behind it; through these are passed pieces of scantling, N, called "needles," which, being about a foot long, enter the wall some 4 or 5 inches and project about the same distance from the outside of the plank, thus forming an abutment on the top of the shore S, wedges, *w w*, being inserted so as to make up for any opening or inequality in the joint. Wooden cleats, C, are generally nailed above the needles so as to give them additional strength.

Horizontal Shores.—In cases where one or two houses are taken out of a row the external party walls of those remaining are supported by horizontal shores of different forms, such as those shown in Fig. 14.

If the opening be narrow and the height to be supported moderate, as at A, Fig, 14, the shore may consist simply of a horizontal balk connected with struts abutting against planks, which serve to distribute the support over a greater height of wall, and may be secured to it by needles as above described.

When the walling to be supported is higher, a combination of two such shores may be made, as shown at B, Fig. 14.

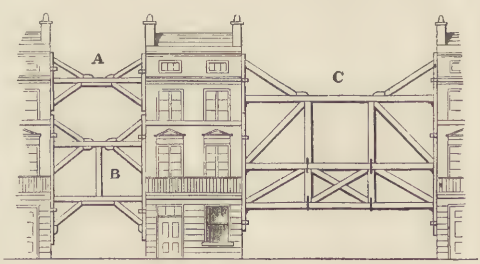


Fig. 14.

If the opening be of considerable extent the shoring may be of a more elaborate character, forming deep trusses, as at C, Fig. 14, placed at intervals of a few feet throughout the depth of the buildings.

When a passage is formed between two houses and they

have to be strutted apart permanently, the shores may be of iron, such as old rails, bent and secured in a form similar to A, Fig. 14.

SCAFFOLDING.

Scaffolds are temporary erections of timber supporting platforms close to the work, on which the workmen stand and deposit their materials.

Bricklayers' Scaffolds.—When a wall is built as high from the ground as the bricklayer can conveniently reach he commences a scaffold by planting a row of poles or "standards," S S, about 10 or 12 feet apart (Fig. 15).

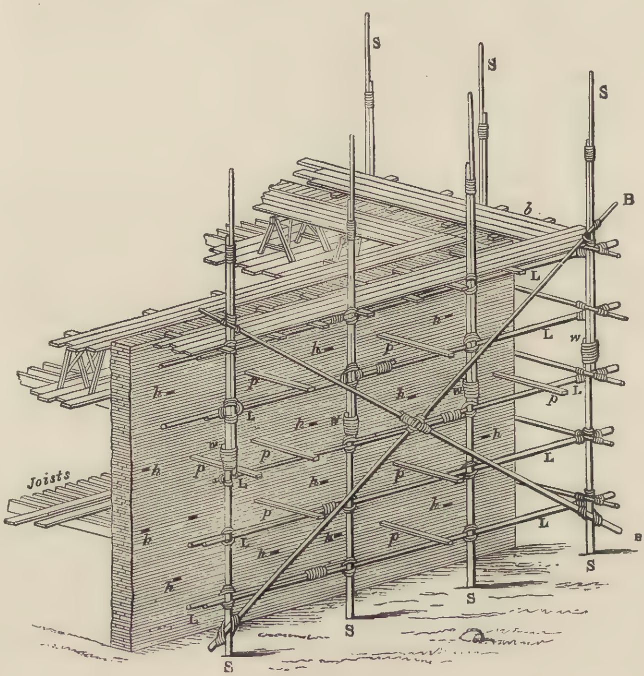


Fig. 15.

Across these standards, at the level of the work already done, are poles, called "*ledgers*," secured with lashings which are in many cases tightened up by wooden keys or wedges, and upon these are laid short transverse pieces called "*putlogs*," *p*, about 6 feet long and 3 inches thick, which form bearers to support the scaffold-boards, *b*.

The putlogs are from 4 to 6 feet apart, according to the strength of the scaffold-boards, which should be about $1\frac{1}{2}$ inch thick; header bricks are temporarily left out, forming holes, *h h*, into which one end of each putlog is inserted, the other end resting upon the ledger.

Three or four scaffold-boards are laid across the putlogs; on these the bricklayer stands and his materials are deposited.

The materials are either carried up ladders in hods, or hoisted by means of a pulley or windlass and rope.

In many cases a platform for landing materials is erected in the same way as the scaffold, and close to it.

When the wall is so high that it can barely be reached from the scaffold-boards another row of ledgers is lashed to the standards, fresh putlogs laid, and the scaffold-boards are raised to the new level.

The ledgers and putlogs used at the lower levels are left in position to steady the scaffold, and if the building be very high and in an exposed situation the scaffolding must be stiffened by lashing long poles, called "braces," B B, diagonally across the outside of the standards and ledgers.

Care must be taken not to load a scaffold too heavily, otherwise the putlogs will injure the green work upon which they rest.

The scaffold for the inside of the brick or rubble walls of buildings sometimes consists merely of planks laid across the joists of the different floors, which are placed in position for the purpose; when the walling has risen more than 5 feet above a floor a fresh tier of planks is provided, supported on trestles, empty casks, or anything that may be available.

When there are no floors on the inside of the wall the scaffold then is constructed in the same way as for the outside.

Masons' Scaffolds.—Scaffolding for ashlar walls, of which the stones can be lifted without machinery, are formed with standards and ledgers; but as putlogs cannot conveniently be inserted in the face of the masonry, a row of standards is used on *both* sides of the wall, between which the putlogs are lashed, so that the scaffolding is entirely independent of the building.

Building without Scaffolds.—In some parts of the country houses many stories in height are erected without scaffolds at all, the work being all done from the inside, and the men supported only by temporary platforms formed on the different floors in succession.

Special Scaffolds.—*Scaffolds made from square scantling* have been used under the supposition that the timber might eventually be used in the building, that cords would be saved, and that the scaffolding could be more quickly erected and taken down.

Practically, however, these advantages have not been found to exist, and, where the scaffolding is high, iron sockets for uniting the lengths of scantling and other expensive and awkward contrivances have been found necessary, so that the system may be considered a failure.

Gabers Scaffolds, made from pieces of flat timber or deals bolted

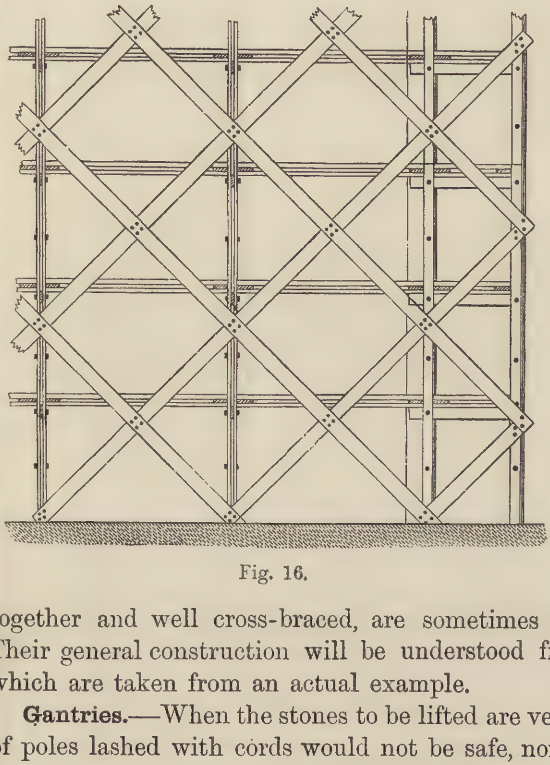


Fig. 16.

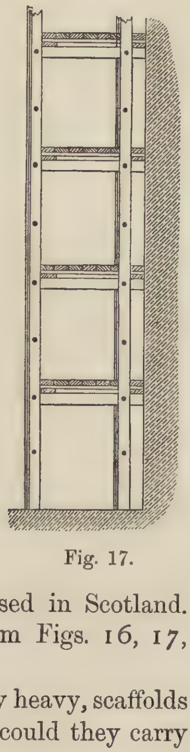


Fig. 17.

together and well cross-braced, are sometimes used in Scotland. Their general construction will be understood from Figs. 16, 17, which are taken from an actual example.

Gantries.—When the stones to be lifted are very heavy, scaffolds of poles lashed with cords would not be safe, nor could they carry the necessary machinery for lifting the stones.

In such a case a staging or "gantry" is erected of balk timber, supporting a tramway, upon which runs a "traveller," extending across the gantry at right angles to the direction of its length, and consisting of a stage on wheels, along which moves a truck carrying a double purchase crab.

As the stage or traveller can move anywhere in the direction

of the length of the scaffold, and the truck can move along the traveller across the width of the gantry, it is evident that the crab can be brought vertically over any point lying within the scaffolding.

The traveller consists of two trussed beams (see Part I.) fixed parallel to one another, and about 4 or 5 feet apart.

At each end the beams are united by a cast-iron carriage containing a pair of wheels, which run along the rails fixed upon the upper beams or sills of the gantry.

The traveller is worked along by turning these wheels, which is effected by machinery worked either from the platform carrying the crab, or by men stationed at the ends of the traveller.

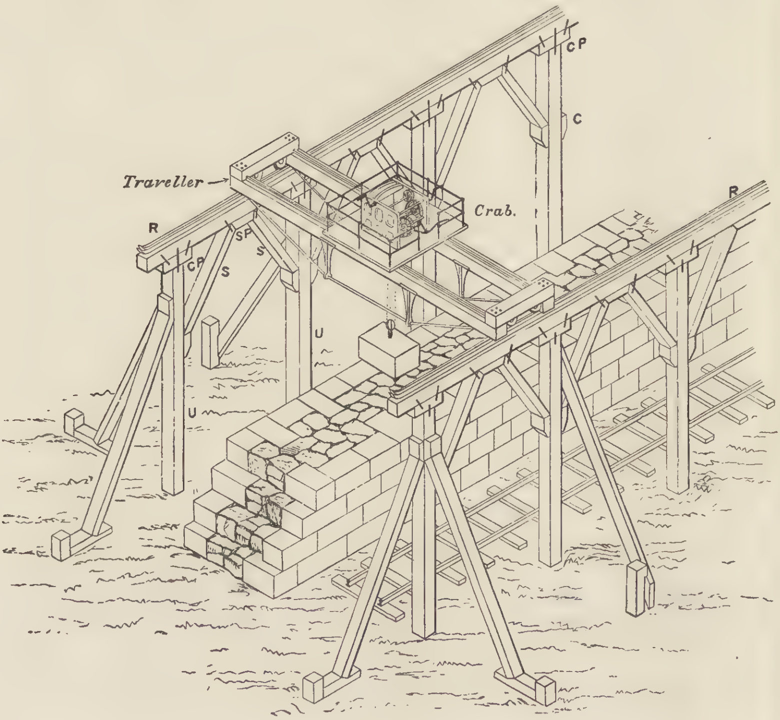


Fig. 18.

The truck carrying the crab is moved along on the rails of the traveller, across the gantry, by machinery on its own platform.

The outer wheels of travellers moving on a circular gantry are made with very broad tires, so that they may not jam upon the rail.

Fig. 18 is a longitudinal view of a gantry constructed of balk timbers. The uprights, U U, are placed from 10 to 20 feet apart according to the size of timber available, and the capsills or "runners," R R, are supported by struts, S S, which butt against a straining piece, SP, and rest upon cleats, C. Corbel pieces are often introduced, as shown at CP.

The standards or uprights at the end of the gantry should be strutted as shown, and so should every standard be supported by struts on the outside to prevent lateral movement.

In order to keep the timber as perfect as possible bolts should be avoided, and the balks united by straps or "dogs."

The latter are pieces of iron about $\frac{3}{4}$ inch square, the ends of which are turned down and pointed by being splayed on the *inside* so as to draw the timbers together when driven home.

It frequently happens that a line of railway can be brought from the stoneyard right under the gantry, as shown, in which case the stone can be lifted off the trucks by the traveller and set at once.

Derrick Cranes of the form shown in Fig. 19 are frequently used for lifting the materials required in building large houses, as well as other structures.

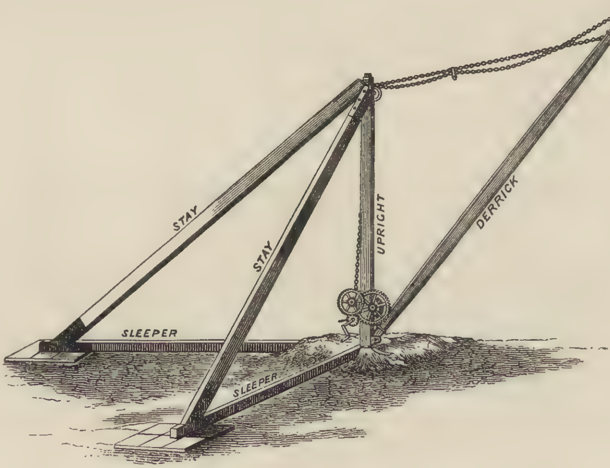


Fig. 19.

The crane is placed on a platform in a high and central position, so that it can reach the stones or other materials where they are deposited, and also by revolving the jib or derrick place them where they are required in the work. The platform is frequently

triangular in plan, supported upon a tripod of lofty timber-latticed columns, the entire structure being braced together; or, as an alternative method, the derrick is mounted upon a traveller on a gantry to increase its effective reach.

Methods of securing stones to be lifted.—It is manifestly of the utmost importance that stones to be hoisted should be simply and safely secured to the chain or "fall" by which they are to be lifted. There are several ways of doing this:—

1. *Chain.*—Rough stones may merely have a chain passed round them; this, however, would injure worked stones, and would be inconvenient while they were being set.

2. *Lewis in separate pieces.*—A hole is cut in the stone, being wider at the bottom than above (see Fig. 20); into it are fitted three pieces of iron of the shape shown; the two side pieces are first placed, then the centre piece, and the three are united by a bolt passing through them. This bolt also secures a ring or shackle, into which the hook of the fall is inserted when the stone is to be raised; as the stone rises, the lewis, in virtue of its wedge shape, becomes tightly jammed into the hole.

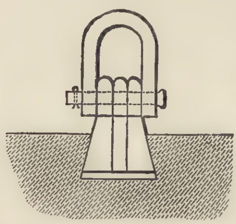


Fig. 20.

3. *Lewis in one piece.*—An improvement on the ordinary lewis, frequently used, is shown in Fig. 21.

In this the chain is attached to a ring passing through the eye (*e*) of the centre piece, *c*, the lower part of which is wedge-shaped.

The side pieces are connected to one another by cross pieces, *cp*, of flat iron on each side of the centre bar; they are hinged to the ends of the cross pieces, and with it are free to move up and down the centre piece.

When the stress comes upon the lewis the centre piece is drawn up, and as the broader part of its wedge rises between the side pieces it forces them out upon the sides of the hole, and the greater the strain the tighter becomes the grip of the lewis.

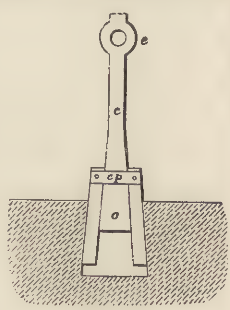


Fig. 21.

When the stone has been lifted a smart tap on the head of the centre piece drives it downwards, the side pieces collapse, and the lewis can be withdrawn.

A great advantage in this lewis is that the pieces are all connected, which saves time, and prevents their being lost.

4. *Lewis for subaqueous work.*—A modification of the lewis (shown in Fig. 22) is used for setting under water. A line is attached to the rectangular piece, after the stone is set this is pulled out, and then the wedge piece can easily be removed.

5. The following is a substitute for the lewis sometimes used for hard stone. Two short bars connected by a chain are let into holes inclined inwards towards the centre of the stone; when the strain comes upon the centre of the chain the bars are pressed inwards and grip the stone.

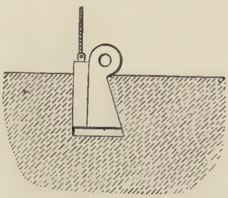


Fig. 22.

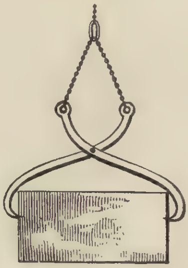


Fig. 23.

6. *Nippers.*—A pair of nippers is sometimes used thus (Fig. 23):—

A small piece is picked out on each side of the stone so as to give the point of the nippers a hold.

The upper ends or "eyes" of the nippers are fixed to a short chain which passes through a ring attached to the fall. When the weight comes upon this chain its effect is to draw the eyes of the nippers inwards, which has a similar effect upon the points and tightens their hold upon the stone.

Care must be taken that these holes in the side of the stone are made so far from the top that the weight will not cause the points to drag up through the stone.

They should of course be so high that the centre of gravity of the stone is below the points, in order that it may not turn over in the nippers.

In all cases where worked stones have to be lifted by nippers care should be taken in working them to leave little projecting knobs to receive the points of the nippers so that the worked face may not be injured. These little knobs can be dressed off when or just before the stone is set.

CHAPTER III.

PLUMBING AND SANITATION.

DRAINAGE.

THE necessity of a well designed and carefully executed system of drainage, and the importance of good sanitary fittings in a building, are now so fully recognised that it will be unnecessary to discuss this question at length. The health of the residents so greatly depends upon good sanitation, that not only should the drainage be as perfect as possible, but each sanitary fitting should be the best of its kind and most suitable for its purpose. During comparatively recent years only has sanitary science been given the serious consideration which the subject demands.

A case came under the writer's notice only a short time back, where in a nobleman's mansion nearly the whole of the closets were "pan closets," and the whole of the traps to sinks, etc., of the "bell" pattern. Many of the latter had the upper bell removed or broken, so that direct sewer gas entered the house in several places. In another instance, a large town house in London, the principal W.C. was placed in the centre of the building, was lighted only by borrowed light, and ventilated directly on to the main staircase. Happily such obsolete fittings are now prohibited by the Sanitary Authorities, and such errors of planning rendered impossible of execution by the various acts dealing with sanitation. At the present time, not only in London, but in the provinces also, Acts of Parliament and local bye-laws have been framed for the purpose of governing these questions.

The first care of every sanitarian should be to keep what is generally known as "sewer gas" out of the building. Unfortunately the presence of foul air is not always detected by the smell, and frequently it is only when illness appears that an examination is made, and the defect or defects discovered. It

may be well to briefly refer to some of the worst forms of fittings and most glaring sanitary defects which are often found in old and sometimes in modern buildings, before describing good forms of fittings and methods of construction.

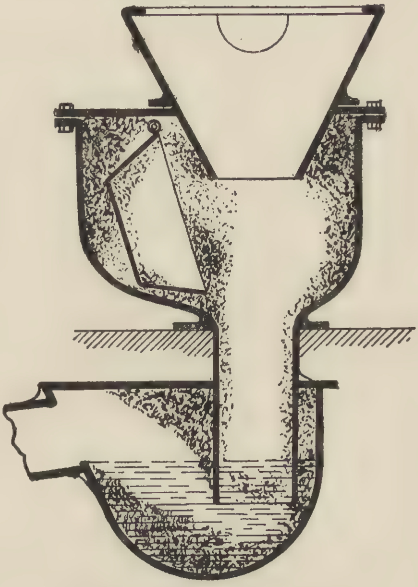


Fig. 24. Pan closet with D trap.

It is difficult to imagine a worse or more insanitary W.C. than that known as the "pan closet." It will be seen from the illustration (Fig. 24) that the pan is hinged at the back, and discharges its contents into the container, which has to be of large size in order to allow for the pan falling backwards. The container becomes fouled by continuous use, and every time the closet is used, dangerous and unpleasant odours pass freely into the house. An old pan closet when removed and examined, presents an indescribable amount of foul deposit.

The "D" trap (Fig. 25) is a most objectionable form of trap, and is practically never used. It will be seen that this trap is not "self-cleansing," and its form altogether favours the retention of foul matter. Frequently old traps are found where the dip pipe has been eaten away above the water-line by the enclosed gases, thus leaving free passage for sewer gas to enter the house. When this trap was used, very often not only the discharge from the closet was brought into it, but also wastes and overflows, as shown in the illustration; these were of course

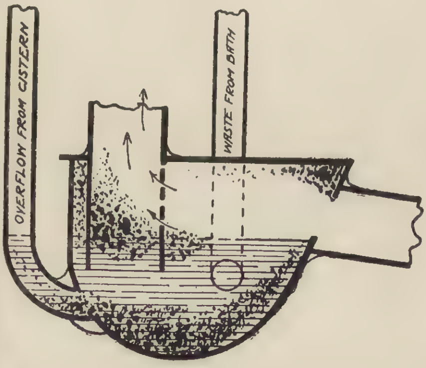


Fig. 25. D trap.

quite free for the passage of foul air, even before the dip pipe had become defective. The "pan closet" and "D trap" were contemporary, and in old houses were almost invariably employed together. It would indeed be difficult to invent any two fittings which, used in conjunction, could combine so many sanitary defects and were so dangerous to health.

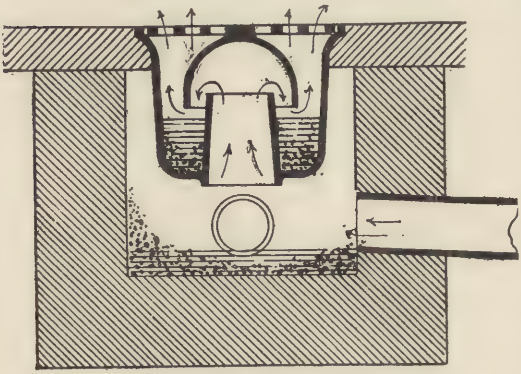


Fig. 26. Bell trap.

Another form of trap, now obsolete, was the "bell" trap (Fig. 26). In addition to having insufficient "seal," the small quantity of water in the trap was easily evaporated in hot weather. The water-way was usually insufficient, which induced careless servants to remove the bell, thus destroying even the little seal which the trap should provide. Insanitary as this trap was, even when properly made, it is frequently found that the lower portion of the bell did not reach the water level of the receiver when fully charged with water, so that it was merely an ornamental appendage which could be (and usually was) thrown aside. When fixed to a sink, the lower portion of the receiver speedily became choked with grease, thus not only collecting foul matter, but blocking up the water-way. The "bell trap" was often fixed in basements to act as a surface gulley, and in this case usually discharged into a brick chamber, which collected foul matter on the bottom and was quite inaccessible for cleaning.

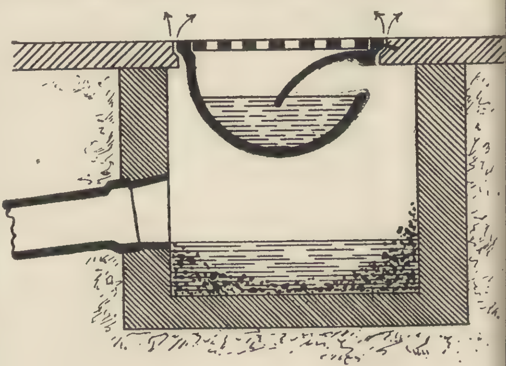


Fig. 27. Lip trap.

Fig. 27 shows a "lip" trap, which it was thought would overcome

all the defective points in the bell trap. It was an improvement on the bell trap, so far as there was no part made removable, and so long as there was water in the trap the seal remained unbroken, but it was never self-cleansing, and like the bell trap was often built over a brick chamber. This in itself was insanitary on account of the large amount of foul matter which accumulated at the bottom, and the effluvium from which would have free passage round the trap if it were not properly set, or through the trap if the seal were broken by evaporation.

Another old-fashioned and defective trap which was largely used is shown on Fig. 28. It will be seen that many objectionable points are in evidence. It is not self-cleansing; the receiver

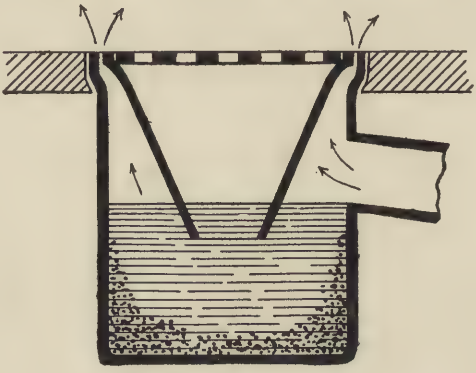


Fig. 28. Defective trap.

would become choked up with filth; and sewer gas would escape between the joints if defective. Perhaps the only good point such a trap possessed was the small water area exposed, rendering a broken seal by evaporation unlikely. On examination of an old house it is often found that the lower portion of the cone had become fouled by grease or other deposit, so that the grating and conical portion of the trap had been removed, thus destroying any seal which should exist in the trap.

In the present day the manufacture of sanitary fittings has been so carefully studied that no difficulty should be experienced in selecting those which are practically perfect, but it is astonishing how easy it is for an ignorant or careless workman to render the best fitting inoperative, and even dangerous to health, by bad workmanship in fixing or want of knowledge in plumbing. A few of such cases which have come under the writer's notice are here illustrated.

A very common defect is that of a broken pipe or pipes occasioned by settlement of a wall through which the drain

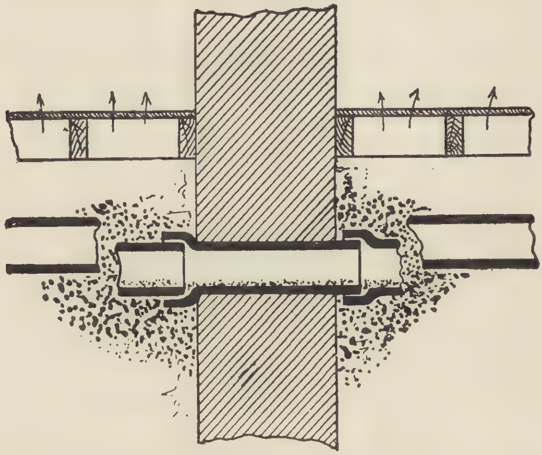


Fig. 29. Drain pipe broken through settlement of wall.

passes (Fig. 29). The result is that the sewage leaks through the fractures, impregnates the soil around, and admits not only sewer gas but effluvia from decomposing matter through the joints between the floor boards. When a drain passes through a wall the probability of settlement (however small) should be guarded against by the aperture being covered over in half brick rings of the number proportionate to the height of the wall and weight it has to carry. A space of about 3 inches should be left between the lower part of the arch and the upper part of the drain pipe. The absence of concrete under stoneware drains has proved a most fertile source of bad workmanship. Until the last few years, concrete was seldom if ever put under stoneware drains, and the

Fig. 30. Sagging drain pipe.

joints were usually made in clay. Fig. 30 illustrates perhaps the most common of all defects occasioned by this inferior method.

Presuming the general line of drainage had been laid straight and with proper fall, the slightest settlement would cause the pipes to sag, with the result as shown. The joints would be forced open and a small cess-pool be created between the pipes, which would eventually increase in bulk, choke up the drain, and the soil around the defective joints would be permeated by sewage. It is not uncommon for many cart-loads of filth to be removed from under an old house from this defect. Leaking joints are perhaps the greatest cause contributing to settlement in a line of drains. It is often found that where settlement has

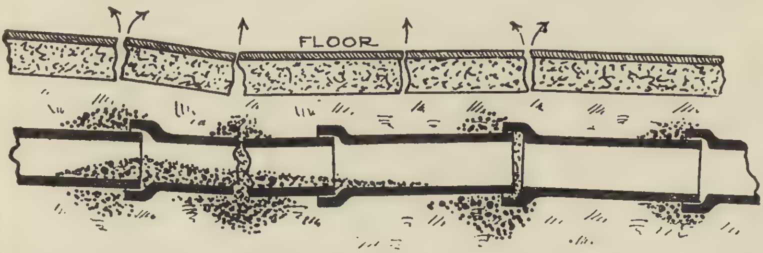


Fig. 31. Broken and defective drain pipe through settlement.

occurred the drain becomes cracked in the centre (Fig. 31) with the same result as in the last instance. Bad jointing between pipes (sometimes of different diameters and oftentimes of different materials) occurs frequently, and should be most carefully guarded against. Fig. 32 illustrates the method often adopted by ignorant workmen for jointing two stoneware pipes of different sizes. The spigot end of one pipe is placed in the socket of the other, and the joint made with clay. It will be readily seen that when the clay joint deteriorates, sewer gas can escape; also that the flow of sewage is impeded and that a stoppage at this point would inevitably occur. When two such pipes (say of 4 inches and 6 inches diameter) are to be jointed, a pipe tapered from one size to the other should always be used; the lower side of the tapered pipe should be fixed horizontally, so that the bottom portion of all the

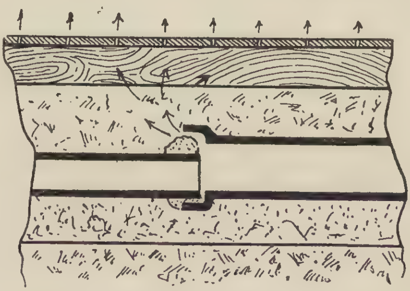


Fig. 32. Defective jointing between drain pipes of different diameters.

drain is kept straight and of an equal gradient. Taper pieces should invariably be employed for connecting drain pipes of differing sizes—whether in iron or stoneware, and the joints made in caulked lead or cement as described later on.

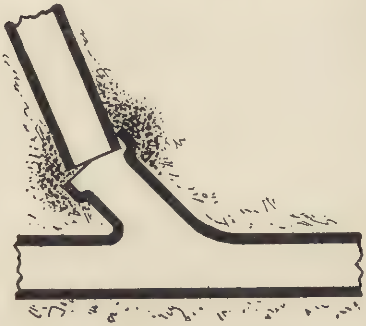


Fig. 33. Plan of defective junction in drain.

Another very common error is made in the execution of splayed junctions. The illustration (Fig. 33) shows a straight junction instead of one curved to an easy bend, with the result that one side of the joint is left open and the surrounding soil contaminated with filth.

Of the many sanitary defects connected with overflows, bypasses, wastes, etc., a few samples are here appended.

A rather interesting one was found a short time back in a west-end residence, and was only discovered after repeated cases of illness among the servants. A dip-stone trap (Fig. 34) was fixed under a scullery sink, and into this the waste (with a bell trap) discharged. It was found that the upper portion of the dip stone was not touching the cover, the bell trap was unsealed, and the chamber of the dip-stone trap had become a small cesspool, so that sewer gas entered the house over the top of the

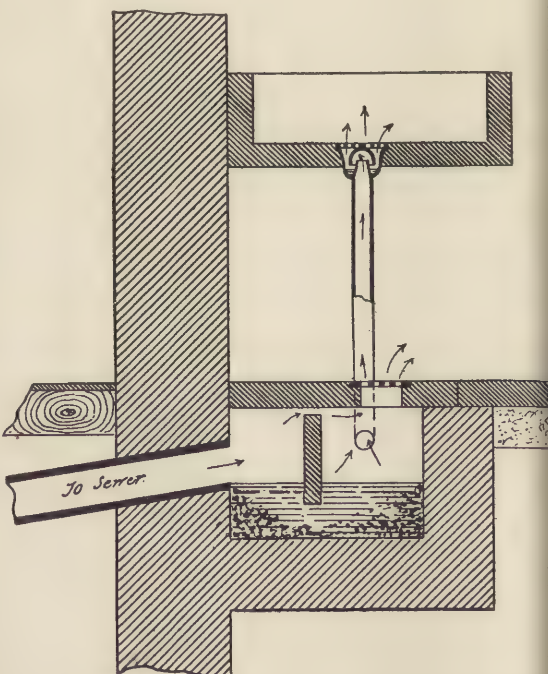


Fig. 34. Defective sink waste with bell and dip-stone trap

stone, through the defective bell trap and through the floor grating, as shown in the illustration.

It is usually found when a trap discharges into a brick chamber, or, as in the case of the dip-stone trap, the brick chamber forms part of the fitting, that the walls have never been rendered in cement. The joints between the bricks therefore become defective and porous, so that the surrounding soil becomes impregnated with foul matter.

Fig. 35 illustrates a case where the waste from the sink was

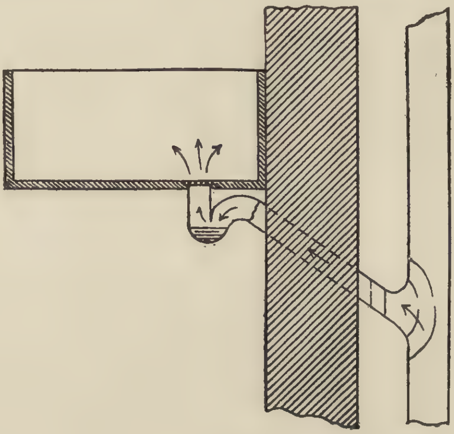


Fig. 35. Defective sink waste carried into soil pipe.

taken directly into the soil pipe. An ordinary trap was fixed underneath the sink, but the large fall allowed caused the trap to be syphoned out whenever the soil pipe was flushed. No antisyphonage pipe had been provided, with the result that the seal in the trap became useless, and therefore direct passage was opened for the entry of sewer gas into the house.

An exceedingly common fault, is fixing the overflow of a bath or lavatory to the sewer side of the trap instead of the reverse, thus causing a by-pass for impure air and rendering the trap perfectly useless. An instance of this is shown on Fig. 36, where it will be seen that free access is given for contaminated air to pass into the house. The overflow should naturally be fixed between the basin and the inner side of the trap.

It should be noted that, on account of the soapy deposit, the air from the wastes of lavatories and baths is particularly offensive, if not prejudicial to health. In addition to this,

however, sometimes the gullies receive the wastes from a sink, so that all the effluvium from the standing water in the trap also passes up the overflow. Instances of soil pipes not being carried sufficiently high above the roof level and dormers, and thus conveying sewer gas into the windows, are of daily occurrence. Vent pipes have sometimes been carried into the nearest chimney flue, so that when a down-draught occurs, sewer gas is conveyed

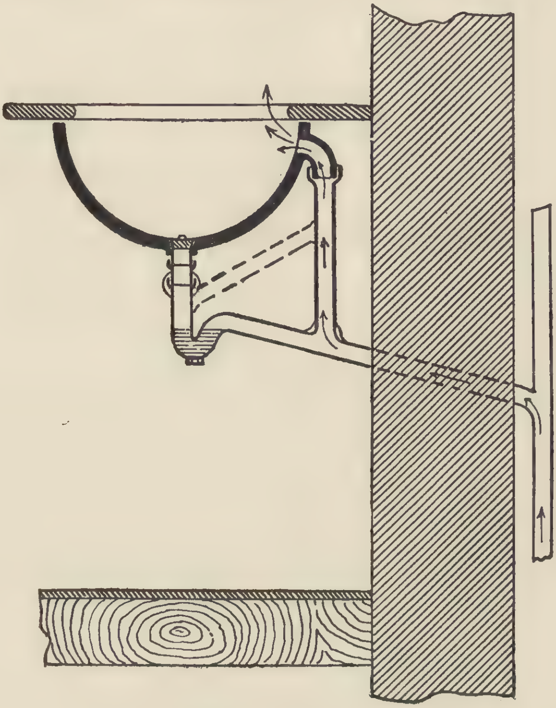


Fig. 36. Defective overflow from lavatory.

into the rooms. A case has come under the writer's notice where, from an apparently simple error in plumbing, a town main was badly contaminated by sewage; and this defect was not discovered for some years. A large volume could be compiled on sanitary defects, some made through ignorance, many from carelessness, and all unjustifiable. As a final example, Fig. 37 shows one of the many ways in which the water in a cistern may become contaminated. The cistern supplies a sink, and provides also for the flushing of a hopper closet without an intervening Water Waste preventer. The supply pipe acts not only as a ventilator

of a filthy fitting, but discharges foul air directly over the water in the cistern.

In this and the following chapter it is proposed to deal with

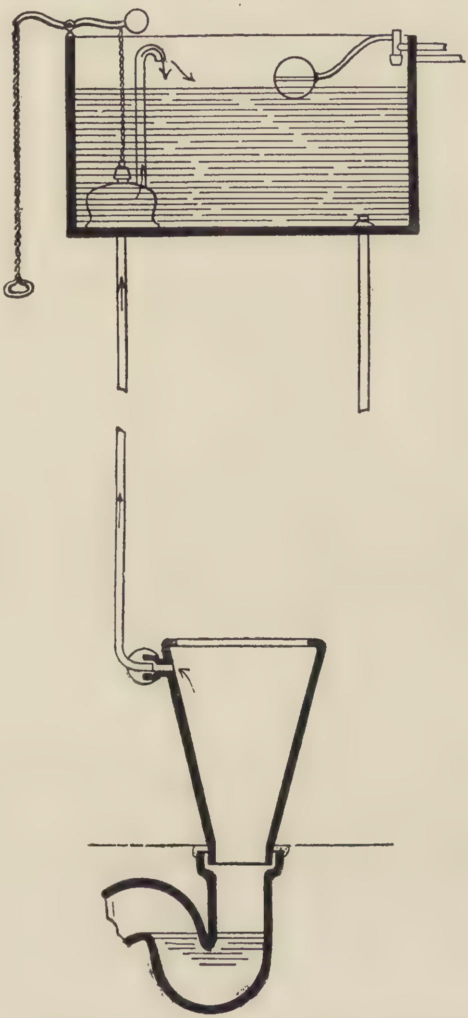


Fig. 37. Water contaminated through defective supply to W.C.

the drainage and fittings of a detached residence. This particular example has been chosen, as such a house would contain nearly the whole of the various types of fittings which are in general use. The question of sewering and sewage disposal is such a

large one that it cannot be brought into the scope of the present work, and it has therefore been assumed that the sewer is already constructed in the road facing the house.

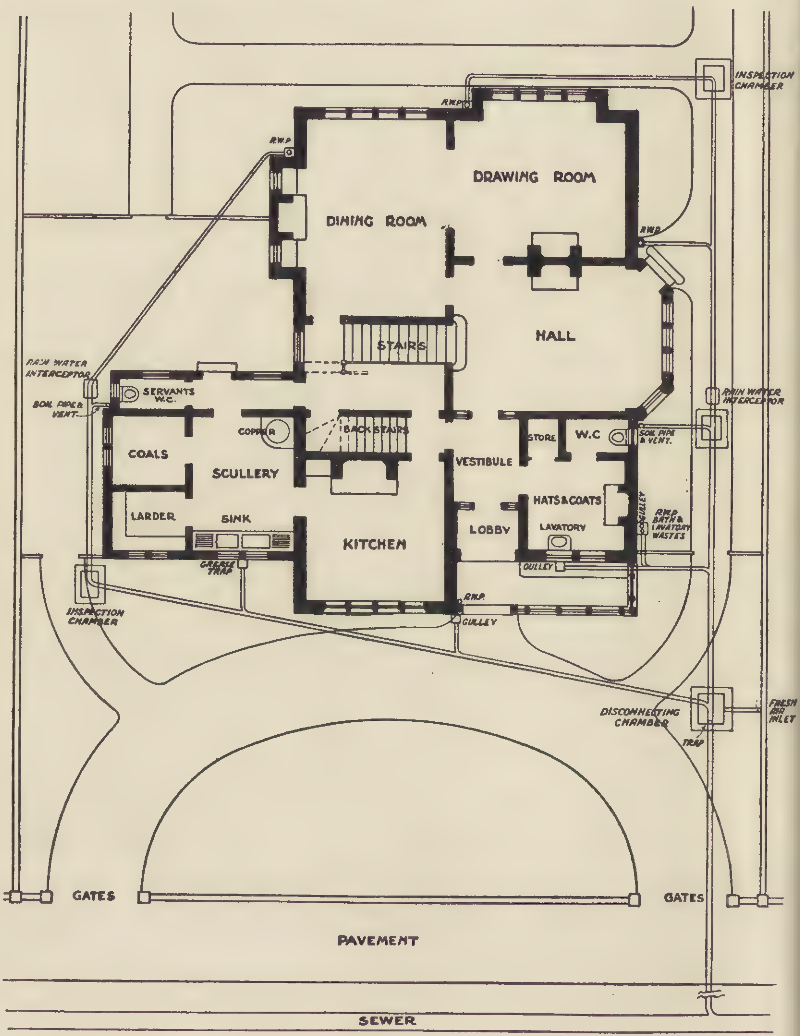


Fig. 38. Ground-floor plan of residence.

The general principles which govern a good system of drainage are: (1) that all the drains, where practicable, shall be laid outside the building; (2) that a continuous current of fresh

air must pass throughout the system by means of inlet and exhaust ventilators; (3) that each fitting must be separately trapped to prevent the entrance of any foul air into the building;

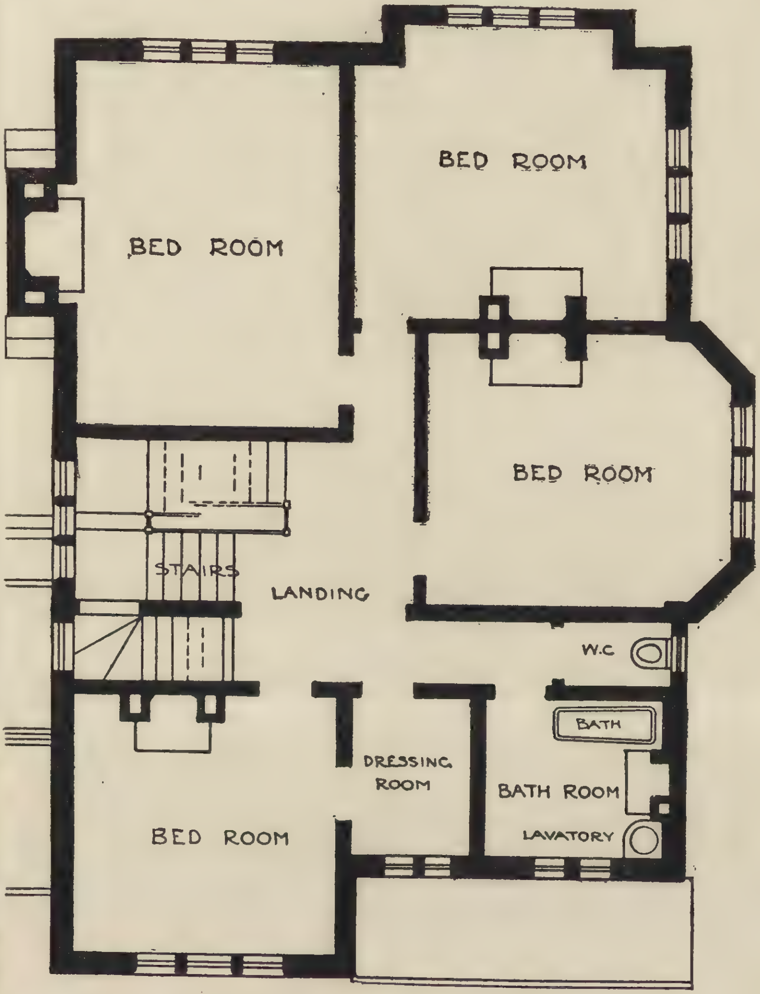


Fig. 39. First-floor plan of residence.

and (4) that every part of the system must be easily accessible for cleaning, sweeping, and repairs.

Figs. 38, 39, and 40 show the ground, first, and second floor plans of the residence, with the various fittings and system of drainage. In order to prevent sewer air from entering the drain, a

Disconnecting Chamber is placed as near the boundary fence as possible. Fig. 41 illustrates a very good type of disconnecting chamber. The walls are built of brickwork in cement, 9 inches

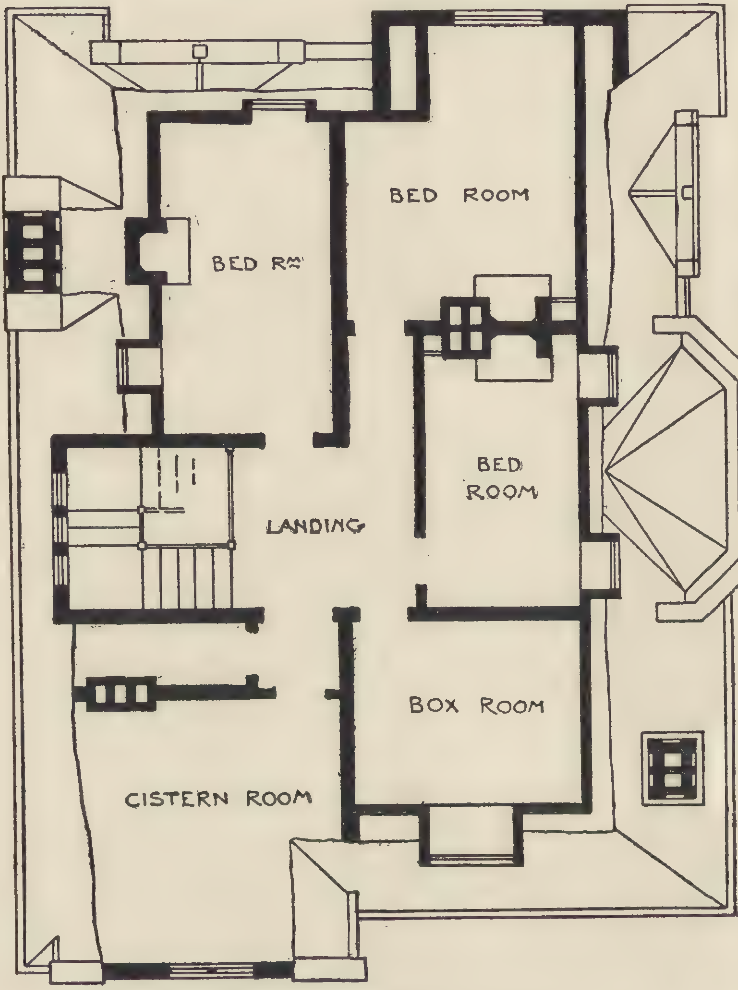


Fig. 40. Second-floor plan of residence.

thick, and the inside rendered in Portland cement trowelled to a smooth surface. In high-class work, the walls are frequently built in white glazed bricks,—an admirable arrangement for cleanliness and durability. It will be seen from the illustration that the drain enters the chamber from the side nearest the

house, whilst on the sewer side is fixed the disconnecting trap, with a good water-seal. A sweeping arm is provided above the trap, at an angle convenient for working the rods, in order to remove any obstruction which might occur between the

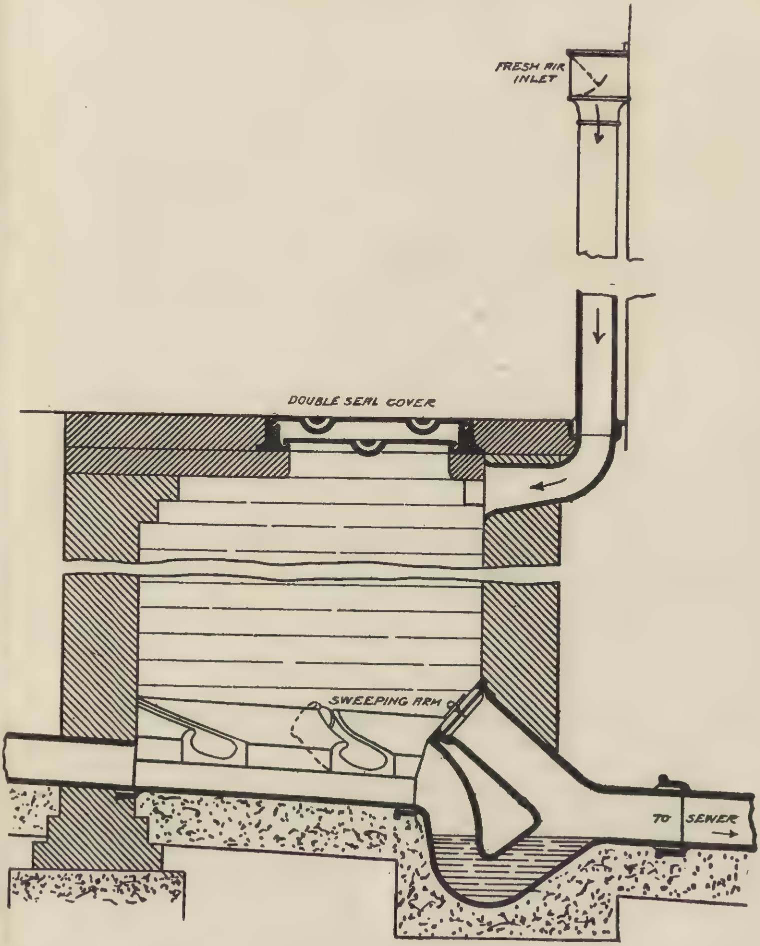


Fig. 41. Section of disconnecting chamber.

chamber and the sewer. The sweeping arm is provided with an air-tight expansion stopper which would only be removed for the purpose of inserting the rods. The bottom of the chamber is formed by a three-quarter channel pipe of the same diameter as the drain. These channel pipes are sometimes put in of half-

diameter only, but this is inadvisable, as a heavy flush of water splashes the sewage over the top of the pipe, and foul matter becomes deposited on the "benched" sides. When half-diameter pipes only are used, it is advisable to build on either side of the pipe one course of glazed bricks, from which the concrete and cement benching springs (Fig. 42). All junctions in the chamber should be formed by "curl over" inlet channels as shown on the illustration, in order to prevent the sewage splashing upwards. It should be carefully noted that when two or more junctions occur they should never be placed opposite each other, as the discharge from any pipe would be thrown into the one opposite to it. The intervening space between the channel pipe and sides of the chamber should be "benched up" in concrete and trowelled to a smooth surface, so that any moisture or deposit would fall back into the channel pipe. The disconnecting chamber should be made of sufficient size to enable a man to enter it, and at the same time have room to work the cleaning rods. It is unnecessary, however, to have the manhole cover of larger size than about 2 ft. by 1 ft. 4 in., and a portion of the chamber is generally corbelled out at the top as shown.

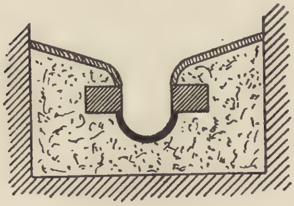


Fig. 42. Channel in disconnecting chamber.

Fig. 43. Double-seal cover to disconnecting chamber.

The best form of cover is that illustrated on Fig. 43, and is known as the "double seal." It is made of galvanised iron and is rendered air-tight by each of the covers having a metal flange, whilst the frame has corresponding chases. These chases are filled with stiff grease and the covers are pressed down into the

rebate, thus rendering them air-tight. When the chamber is a deep one, stepping irons are fixed on one of the walls at intervals of about 12 inches in height. A fresh-air inlet should be connected to the chamber by a trumpet-shaped mouth as shown, and joined to the inlet by a heavy cast-iron vertical pipe and a box inlet provided at the top. The inlet pipe is usually carried on an adjacent wall, or to a tree if there should be one in a convenient position. In order to prevent the inlet acting as an exhaust, a mica flap valve is provided over the open grating of the box, which automatically opens to admit fresh air, but closes if air passes up the pipe (Fig. 44).

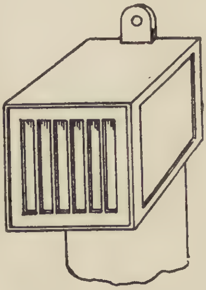


Fig. 44. Fresh-air inlet.

Drains.—The materials usually employed for this purpose are glazed stoneware or cast-iron. There is no doubt that the latter material is greatly superior, as only about a quarter of the number of joints are necessary as in stoneware pipes. They are more quickly fixed, a water-tight joint is more easily made, and they are less liable to fracture through any settlement which may occur either in the ground or in the walls of the building. In the best modern work, iron pipes are now generally used, and they are imperative where the drains must necessarily pass under a building, such as in the case of one of a terrace of houses.

Until the last few years, it was customary to make drains much larger in diameter than was needed, and this has been proved to be a mistake, not only from an economic point of view, but also in regard to sanitary fitness. Every drain should be self-cleansing, and in order to attain this end, the pipes should be of a diameter only sufficient to carry away the necessary amount of water. In the scheme here illustrated, the main line of drain should be 6 inches in diameter with 4-inch branches. The gradient or fall of the drains will depend on their length and the depth of the sewer into which they are to discharge. A fall of 1 foot in 40 feet provides an excellent gradient, but it is often found that the sewer is too high to admit of this fall, especially when a basement has to be drained. When the fall has necessarily to be made very slight, it is advisable to fix an automatic flushing tank at the head of the drain, which will discharge at intervals and periodically cleanse the whole line of pipes. Friction

occurs where there is any change in direction, and in order to allow for this, an additional fall should be given, varying from 1 inch to 3 inches. It is imperative that the whole of the joints between the lengths of drain pipes should be perfectly water-tight, and that all drains, whether in iron or stoneware, should be laid on a proper bed of concrete 6 inches thick, except in the very occasional cases where the subsoil is of rock.

The iron pipes should be of heavy section and of water-main strength. The following Table shows the thickness and weights of iron pipes suitable for drain work :—

Bore of iron pipe.	Net length when laid.	Thickness of metal.	Depth of socket.	Weight of pipe.		
4 inches	9 feet	$\frac{3}{8}$ of inch	3 inches	1 cwt.	1 qr.	24 lbs.
6 ,,	9 ,,	$\frac{7}{16}$,,	$3\frac{1}{2}$,,	2 ,,	1 ,,	27 ,,

Iron drain pipes should be invariably coated inside and out with one of the many solutions on the market for their preservation in order to avoid oxidation. The usual method employed is to dip the pipe into a mixture of pitch, coal tar, and linseed oil, the bath being kept at a temperature of about 300° to 400° Fahr. A recent process has been introduced, by which the interior of the pipe is coated with a glass enamel, and when pipes are so treated the exterior of the pipe should be given three coats of coal tar or three coats of "anti-fouling paint," which is usually used for painting the part of ships below water line.

The method usually employed in jointing iron pipes is illustrated

Fig. 45. Jointing iron drain pipes.

on Fig. 45. A few strands of yarn are caulked in between the spigot end and the socket of the adjoining pipe, and the intervening space filled in with molten lead which, after cooling, is well caulked.

The main features of good stoneware pipes are as follows:

They should be (1) made of imperishable material; (2) impermeable to water; (3) uniform and true in section; (4) perfectly straight and cylindrical; (5) sufficiently strong to resist a heavy crushing load or fracture by bursting. The jointing of stoneware pipes is somewhat more difficult to accomplish satisfactorily than in the case of iron pipes. The method usually employed is to make the jointing in Portland cement and sand (Fig. 46) mixed in equal proportions. Care must be exercised that each joint is carefully cleaned on the inner bore of the pipe immediately after it has been made. A frequent cause of trouble arises from the neglect of the above precaution, as the cement often percolates through to the inner bore of the pipe, hardens, and then impedes the flow of sewage by collecting paper and other substances, which gradually accumulate and choke up the pipe.

Fig. 46. Jointing stoneware pipes.

The internal diameter, thickness, weight, etc., of a few stock sizes of stoneware pipes are given in the following Table:—

Internal diameter.	Length.	Thickness.	Depth of socket.	Weight per foot.
4 inches	2 feet	$\frac{11}{16}$ inch	$1\frac{3}{4}$ inches	$10\frac{1}{2}$ lbs.
6 ,,	2 ,,	$\frac{3}{4}$,,	2 ,,	$17\frac{1}{2}$,,
8 ,,	2 feet 6 inches	$\frac{7}{8}$,,	$2\frac{1}{4}$,,	26 ,,
10 ,,	2 ,, 6 ,,	$\frac{15}{16}$,,	$2\frac{1}{2}$,,	36 ,,

A very large number of patent joints are in the market and have been used to some extent, but a good cement joint if properly made is quite satisfactory. Care, however, must always be taken that the cement has been properly cooled before use. It frequently happens that by neglecting this precaution, the cement in the joints swells and cracks the sockets of the pipes, thus making the drain leaky.

Wherever a junction or change of direction occurs in a system of drainage (except at times in the case of a rain-water junction), an inspection chamber should be built. These are usually 3 ft. long by 2 ft. 6 in. wide, in order that room may be provided for working the sweeping-rods and that periodical inspections may be made of the efficient working of the drains. A good type of

inspection chamber is shown on Fig. 47. The construction is somewhat similar to that of a disconnecting chamber, with the exception that no intercepting trap is here necessary. The chamber should be built in 9 inch brickwork with glazed bricks or cement rendering, and should have "double seal" covers, channels and junctions as previously described for the disconnecting

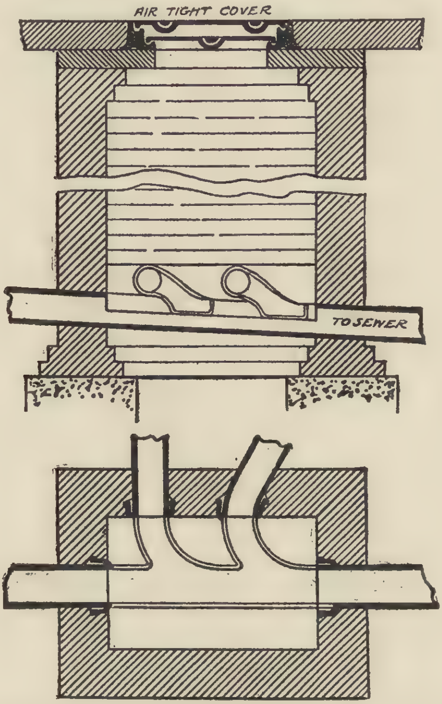


Fig. 47. Plan and section of inspection chamber.

chamber. The central channel should be of $\frac{3}{4}$ diameter and the junctions executed in "curl over" pipes as in a disconnecting chamber.

In planning any system of drainage, great care should be exercised that no portion of it is double trapped. This would have the effect of rendering that part of the drains between the two traps quite unventilated. It should also be borne in mind that outlet ventilators are practically useless unless inlet vents are also provided, so as to cause a continuous current of fresh air throughout the system.

In designing the drainage for a large building it is often

desirable to have one system of pipes for rain-water and another for the foul matter. In some districts, two sewers are provided by the Local Authorities for these purposes. When the separate systems are employed, the rain-water may be conveyed into storage tanks, with an overflow in case of excessive rain, and the soft water thus stored be used for gardening or other purposes, or it may be taken direct into the rain-water sewer.

Frequently a separate rain-water system is laid down and the rain-water conveyed directly to the sewer. In this case a disconnecting chamber should be built similar to that for the foul drain, with a fresh-air inlet, and the rain-water pipe should discharge over untrapped gullies, so that a continuous current of fresh air passes throughout the pipes.

The usual method of dealing with the rain-water of a building of the size illustrated is shown on the plan. Where the rain-water drain joins the foul drain, a rain-water intercepter, as shown on Fig. 48, is fixed. In hot weather there is a danger of these intercepters becoming unsealed by evaporation, and on these occasions it is always advisable to see that they are periodically charged with water. It will be seen from the illustration that an open iron grid is provided, for ventilation, on the clear-water side of the intercepting trap whilst a sweeping arm, with air-tight cover, is arranged on the side next the foul drain.

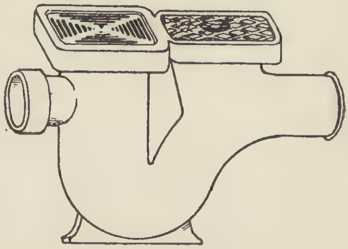


Fig. 48. Rain-water intercepter.

Chapter IV.

SANITARY FITTINGS.

THE water-closets are perhaps the most important fittings in any building, and should receive the greatest attention in selection. The main features of a good closet are: (1) that it should have a large water area, so that the sides of the pan may not become fouled; (2) a good water-seal, at least $1\frac{3}{4}$ inches deep; (3) that the whole of the contents of the pan should be discharged through the trap by one flush of water from a 2-gallon cistern; and (4) that the basin and trap should be at the same time fully charged with water.

Innumerable kinds of closets are manufactured by makers of sanitary goods. Some contain all the above requirements, and many only a few of them. Of the old closets, the "pan," "long hopper," "wash-out," and "plunger" have practically disappeared from the market. None of these closets were self-cleansing, and they possessed so many sanitary defects that they are never fixed in modern work.

The closets generally employed at present are the "wash-down," "valve," and "syphonic"; of each of these types the well-known sanitary engineers make many patterns. For the purpose of illustration it is assumed that in the residence shown in Figs. 38, 39, and 40 a syphonic closet would be fixed adjoining the hat- and cloak-room, a wash-down closet for the servants, and a valve closet on the first floor. Each of these forms will be illustrated and described, although of course any one type might be used throughout the building if preferred.

The syphonic-action closet is one which has been introduced within the last few years only. As will be seen from the illustration (Fig. 49), the outlet of the basin is in the form of a syphon, so that when the contents of the pan are discharged, syphonic action is set up, and the water is syphoned, or drawn

out, with considerable force. Most of the London Water Companies require that no flushing cistern shall be used of a greater capacity than 2 gallons; but in districts where this regulation is not in force, it is always desirable to fix cisterns of 3 gallons capacity. Manufacturers have been endeavouring to make fittings efficient with the standard minimum amount of water, and many have succeeded. However, before selecting any W.C. fitting, it is desirable to ascertain definitely that this limited amount of water will be sufficient to clear the basin and re-charge it and the trap. The syphonic closet here illustrated has a water area of 13 inches by 9 inches by $5\frac{1}{2}$ inches deep, and the vitiated air between the trap and the closet pan is discharged into the drain or by means of a "puff" pipe fixed above the trap. A mistake frequently made is to carry the puff pipe into the soil pipe instead of taking it through the wall separately. In the former case, this pipe frequently acts as a by-pass for foul air. Care should also be taken that the pipe is fixed in such a manner that any paper or solid matter does not wash up against it when the trap is emptied by a discharge. Fig. 50 shows a puff pipe placed in the wrong position and also, in dotted lines, the pipe as it should be fixed. In the syphonic closets first introduced, it was found that by emptying slop water into the pan, syphonic action occurred and the water-seal in the pan was thus rendered useless. But this difficulty has been overcome in most of the latest patterns of this closet, so that the syphonic action only

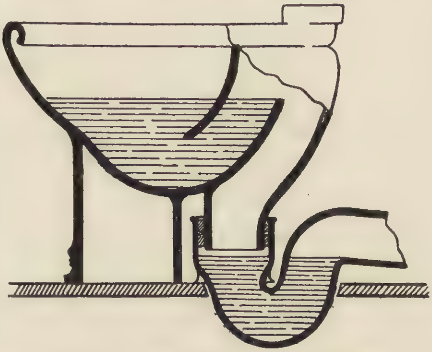


Fig. 49. Section of syphonic closet.

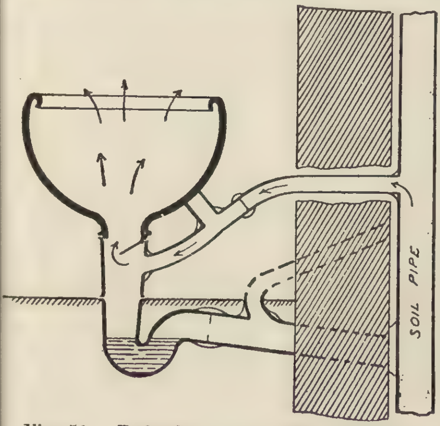


Fig. 50. Defective position of a puff pipe.

takes place when the contents of the cistern are discharged. It should be noted that extreme care and knowledge are necessary in fixing these closets, and whenever possible such work should be performed by the employés of a sanitary engineer, rather than by the very often unskilled village plumber. It has become a saying amongst plumbers that, at times, these closets "take cold," implying that they do not act properly, usually from some very slight defect. This is generally found to be occasioned through bad fixing, and is often remedied in a few minutes by a plumber who is used to this particular class of work.

Wash-down Closets.—The form of closet now most generally used and perhaps the least complicated and best, is the "wash-down." There are innumerable forms of this closet manufactured,

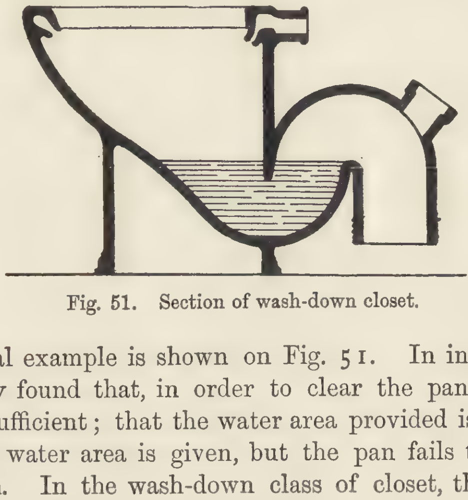


Fig. 51. Section of wash-down closet.

and a typical example is shown on Fig. 51. In inferior types it is frequently found that, in order to clear the pan, one flush of water is insufficient; that the water area provided is too small, or that a large water area is given, but the pan fails to be cleansed by one flush. In the wash-down class of closet, the contents of the pan are forced out by the rush of water instead of being drawn out as in the case of the syphonic. The apparatus requires less delicate fixing than the syphonic and is less expensive. Every closet must necessarily be trapped at the outlet to prevent the passage of foul air into the dwelling, and also an anti-syphonage pipe must be provided to prevent the unsealing of the trap by momentum. The fresh-air inlets and exhausts on the soil pipe and drains ensure sufficient ventilation on the sewer side of the trap.

Valve Closets.—The really good valve closet is a perfectly sanitary fitting, but so many cheap and inferior articles are sold, that extreme care should be exercised in selection. A good sample is illustrated by Figs. 52 and 53. The contents of the

pan are discharged by momentum, and therefore the possible

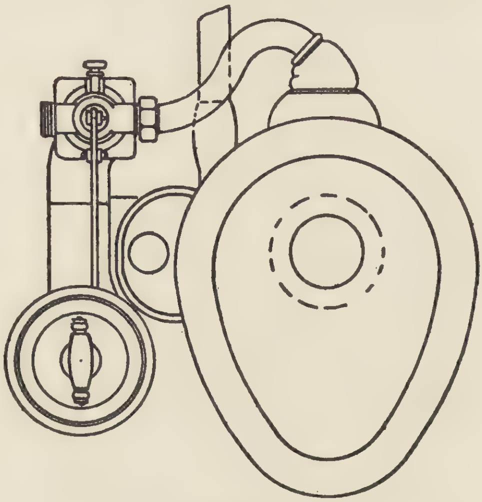


Fig. 52.

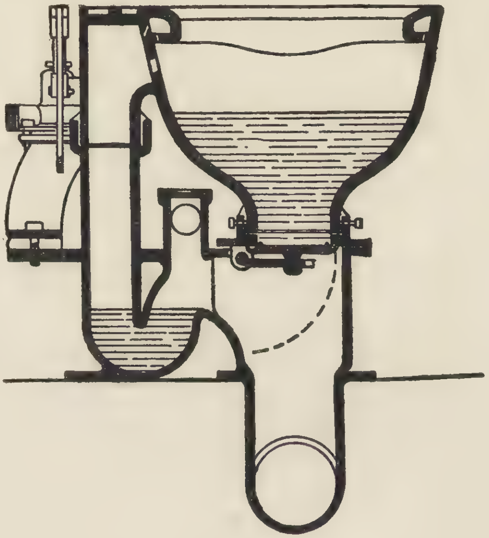


Fig. 53.
Plan and section of a valve closet.

defect of syphonic or flushing action is avoided. But in this form of closet another difficulty arises, namely, the possibility of paper or other solid substances becoming fixed between the valve

and the lower part of the basin. In all good types, however, this is obviated by an arrangement of the basin and the portion over the crank side of the valve being made to "sail over," so as to direct the passage to the opposite side where the opening into the valve box is wide. The valve closet should have an exceptionally large water area and of ample depth, so that soiling the sides of the pan is impossible. Very frequently water-closets are also used for the reception of slops and also as urinals. For this purpose lifting seats are employed, usually made of hard wood, such as mahogany or oak, and a porcelain top is fixed between the top of the closet pan and the seat in order to avoid slopping or dripping. Such a top is shown on Fig. 54, and this arrangement should always be adopted if the W.C. is to be utilised for the above purposes.

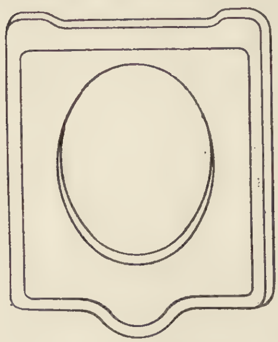


Fig. 54. Slop and urinal top to W.C.

In old work, the W.C. fitting was invariably enclosed by a seat extending the whole length of the W.C. apartment, and with a fixed wooden front. Such enclosures are now quite contrary to modern practice, as the closets are usually fixed without enclosures of any kind, in order that the whole of the fitting and floor may be easily accessible for cleaning purposes. In cases, however, where a client desires to enclose the fitting, polished hard wood should be employed, and the whole of the enclosure should be made with hinged doors, or easily removable fronts, for access. A lead safe should be provided under each closet, with an overflow pipe carried to the open air and a flap valve of copper or brass provided at the outer end.

Assuming the closet to be a good one, it is most important that the connection between the trap and soil pipe should be properly made. In the Public Health Act 1891, various methods of jointing are enumerated, and, as these are usually adopted, not only in London, but in the provinces, extracts from the Act are here given:—

(*a*) In all cases where a person connects a lead trap or pipe with an iron soil pipe or drain, he shall insert between such trap or pipe and such soil pipe or drain a brass thimble, and he shall connect such lead trap or pipe with such thimble by means of a wiped or overcast joint, and he

shall connect such thimble with the iron soil pipe or drain by means of a joint made with molten lead, properly caulked. (This method is illustrated by Fig. 55.)

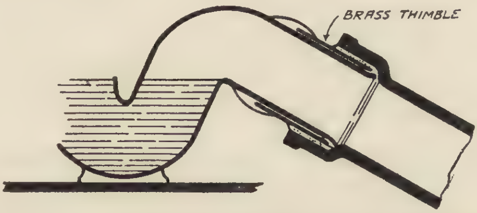


Fig. 55. Joint between a lead trap and iron soil pipe.

It may be noted that the wiped joint between the thimble and the lead trap should be executed in plumbers' solder composed of one part of tin to two parts of lead.

(*b*) In all cases where he shall connect a stoneware trap or pipe with a lead soil pipe, he shall insert between such stoneware trap or pipe and such soil pipe a brass socket or other similar appliance, and he shall connect such stoneware trap or pipe by inserting it into such socket, making the joint with Portland cement, and he shall connect such socket with the lead soil pipe by means of a wiped or overcast joint. (This method is shown on Fig. 56.)

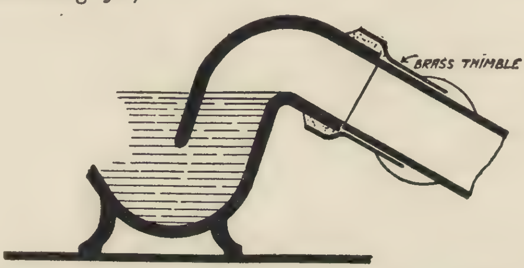


Fig. 56. Joint between stoneware trap and lead soil pipe.

(*c*) In all cases where he shall connect a stoneware trap or pipe with an iron soil pipe or drain, he shall insert such stoneware trap or pipe into a socket on such iron soil pipe or drain, making the joint with Portland cement.

A well-known firm of sanitary engineers have patented a joint, called the "Metallo-keramic" joint, by which the lead pipe may be soldered directly to the earthenware trap of the closet. The fitting is sold with a short piece of pipe connected with the out-go. This is fixed to the earthenware with a thin film of platinum which is fired to the glaze, and to this is soldered the connecting lead pipe.

When a range of closets exists, one over the other, and the

contents are discharged into the same soil pipe, an anti-syphonage pipe is necessary in order to prevent the closet traps being emptied by syphonage or momentum. The position of this pipe is most important, and should be arranged as shown in dotted lines on Fig. 57. It will be seen from the illustration that when the anti-syphonage pipe is fixed immediately on the trap, in a short time after use, paper and solid matter will collect and stop up the entrance. The pipe should always be fixed in the position shown in dotted lines. A case came under the writer's notice where the closet traps were constantly syphoned out although anti-syphonage pipes had been provided, and only after careful examination it was found that the pipes had been fixed immediately over the out-go of the trap, so that they became choked up with paper and were thus quite useless.

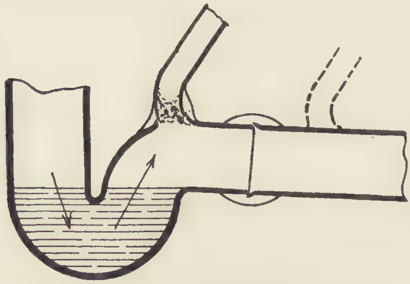


Fig. 57. Incorrect and correct position of anti-syphonage pipe.

Flushing Cisterns.—The London County Council have, in Clause 3 of the Public Health Act 1891, laid down the following rule:—

> Every person who shall construct a water-closet in connection with a building shall furnish such water-closet with a cistern of adequate capacity for the purpose of flushing, which shall be separate and distinct from any cistern used for drinking purposes, and shall be so constructed, fitted, and placed as to admit of the supply of water for use in such water-closet, so that there shall not be any direct connection between any service-pipe upon the premises and any part of the apparatus of such water-closet other than such flushing cistern.

As previously mentioned, the London Water Companies usually prohibit a cistern of more than 2-gallons capacity. A large number of flushing cisterns are on the market, but very many of them are exceedingly noisy, and unpleasantly advertise the fact that the W.C. is in use. Several manufacturers claim that their fittings are noiseless, but really very few of them are so. These cisterns are usually known as "water-waste preventers" on account of the limited amount of water which is discharged each time the chain is pulled, a second flush being only obtainable after the cistern has been refilled. It has been

found by experience that usually a 2-gallon flush is really not sufficient for the removal of matter from the soil pipe into the drain, so that wherever possible a 3-gallon cistern should be fixed. A good type of flushing cistern is illustrated by Fig. 58. When a flushing cistern is arranged to supply a valve closet, it must be so made for an "after-flush" to partially fill the closet when the valve of the pan has been closed.

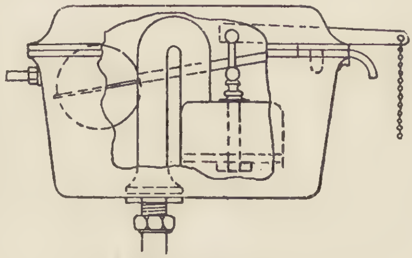


Fig. 58. Flushing cistern or water-waste preventer.

Soil Pipes.—Soil pipes are usually constructed either of lead or iron. They should always be taken up external walls, and carried full bore well above the levels of roofs or dormers to act as exhaust ventilators. The London County Council's requirements as regards soil pipes are as follows:—

Any person who shall provide a soil pipe in connection with a building to be hereafter erected shall cause such soil pipe to be situated outside such building, and any person who shall provide or construct or refit a soil pipe in connection with an existing building shall, whenever practicable, cause such soil pipe to be situated outside such building, and in all cases where such soil pipe shall be situated within any building, shall construct such soil pipe in drawn lead, or of heavy cast iron jointed with molten lead and properly caulked.

He shall construct such soil pipe so that its weight in proportion to its length and internal diameter shall be as follows:—

Diameter.	*Lead.* Weight per 10 ft. length.	*Iron.* Weight per 6 ft. length.
	Not less than	Not less than
$3\frac{1}{2}$ in.	65 lbs.	48 lbs.
4 ,,	74 ,,	54 ,,
5 ,,	92 ,,	69 ,,
6 ,,	110 ,,	84 ,,

Every person who shall provide a soil pipe outside or inside a building shall cause such soil pipe to have an internal diameter of not less than $3\frac{1}{2}$ inches, and to be continued upwards without diminution of its diameter, and (except where unavoidable) without any bend or angle being formed in such soil pipe, to such a height and in such a position as to afford by means of the open end of such soil pipe a safe outlet for foul air, and so that such open end shall in all cases be above the highest part of the roof of the building to which the soil pipe is attached, and, where practicable, be not less than 3

feet above any window within 20 feet measured in a straight line from the open end of such soil pipe.

He shall furnish the open end of such soil pipe with a wireguard covering, the openings in the meshes of which shall be equal to not less than the area of the open end of the soil pipe.

The joint between the soil pipe and the drain, if the former is in lead and the latter in iron, should be made in a similar manner to that shown on Fig. 55. The joint between a lead soil pipe and earthenware socketed drain is made in a somewhat similar way except that Portland cement is used in place of the lead caulking.

Position of Water-Closets in a Building.—This is a most important question in planning, and the previously mentioned W.C. apartment in the centre of the building, ill-ventilated and ill-lighted, would now happily be prohibited. The bye-laws made by the London County Council and by most of the provincial Sanitary Authorities state that at least one wall of a W.C. shall be an external wall, and that it shall be lighted and ventilated by a window at least 2 feet superficial, opening on to an open space of at least 100 feet superficial, and that no W.C. may be approached directly from any habitable room. These requirements are supplemented by many others as to fittings, joints, flushing cisterns, etc., many of which have been previously enumerated. As regards the ventilation of a W.C. apartment, it is usually found sufficient if sash windows are provided, with the upper sash kept continuously down a few inches, or if casements are provided with the usual stays for keeping the casement open. An excellent automatic arrangement has, however, lately been introduced by a leading firm of sanitary engineers. A small circular ventilating fan is fixed at the ceiling level, and this is driven, by the water used for flushing the closet, on its passage thereto. About 300 cubic feet of vitiated air is thus removed each time the fitting is used, and the motive power is obtained free of cost.

In fitting up a W.C. the wall covering should be of some impervious material, such as glazed brick or tiles, and the floors of unglazed tiles or mosaic.

Urinals.—In a building of the size illustrated, urinals would not be required, as the W.C. apparatus would be used for this purpose, and provided with lifting seats, or those raised automatically by balance weights. In large buildings, however,

separate urinals are a necessity, and therefore two leading types of these fittings are here given.

The urinals are, perhaps, the most difficult of all sanitary fittings to arrange quite satisfactorily, as, owing to the chemical constituents of urine, decomposition rapidly occurs, and offensive odours—principally ammonia—quickly result. The apartment containing urinals should be amply ventilated, and a good flush

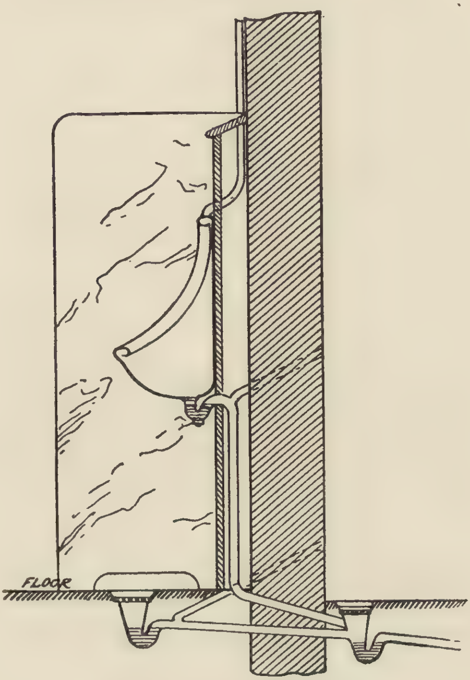


Fig. 59. Basin urinal.

of water provided so that fittings can be automatically cleansed at stated intervals. They are usually made as "basin" or "stall" urinals; the former for residences, clubs, etc., and the latter for schools, public conveniences, or other places where they will be subject to hard wear and tear. A "basin" urinal is illustrated on Fig. 59, and the "stall" pattern on Fig. 60. The basin of a urinal is usually executed in porcelain with a flushing rim, and the contents should discharge through a trap into an open trapped gully outside. A trapped gully with an open grid—usually of gun metal or brass—should be fixed under the fitting to take away surface water or drippings. This trap should be connected

with the outer gully trap and be provided with a puff pipe discharging into the open air. The "stall urinals" are usually either circular or triangular in section, and discharge into a trapped gully on the foot of the fitting as shown. The floors of urinals should be invariably made of a non-absorbent material,

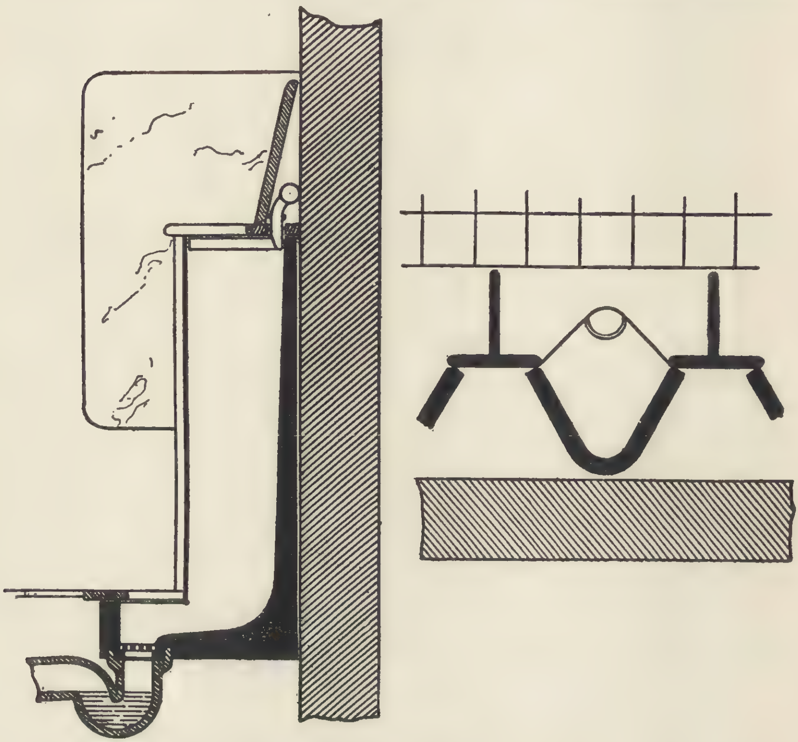


Fig. 60. Plan and section of stall urinal.

such as unglazed tiles or mosaic. An automatic flushing cistern is fixed over each range of urinals so as to discharge at intervals. The divisions of the stall urinals are made of painted or enamelled slate or marble.

Lavatories.—These are generally made of porcelain, with the tops either of the same material or of polished marble, and should be fitted with both hot and cold supplies. The basins are either fixed or rest on pivots, the latter being known as "tip-up" basins. In the latter case, the basin should always be made so that it can easily be lifted out for cleansing purposes, as the inner container is likely to become fouled by soapy deposit. It is always

advisable to leave the fitting entirely free from any enclosure, in order that access for repairs is rendered easy, and the whole of the fitting can be readily cleansed. This can be accomplished by supporting the lavatory on an open frame-work of hard wood or on cast-iron brackets.

A good form of basin lavatory is illustrated on Fig. 61, and is known as the D shape. The waste here shown is a "stand-up," but an ordinary plug and washer may equally well be used. The stand-up waste has the advantage that no overflow pipe is necessary, the waste acting also in this capacity.

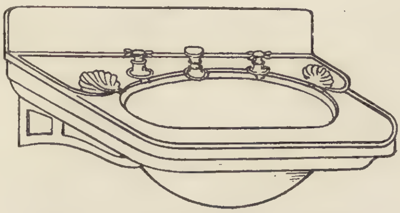


Fig. 61. D-shaped lavatory basin.

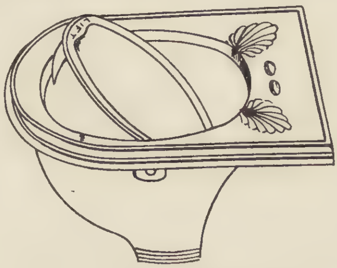


Fig. 62. Tip-up lavatory.

Fig. 62 shows a "tip-up" basin lavatory. The outer basin is supported on pivots, and in order to empty the contents, the basin is raised from the front and discharges into the inner receiver connected to the waste. The trap under a lavatory should be provided with a brass screw cap for cleansing, and in the case of a range of lavatories the screw cap should be so fixed as to enable the whole length of waste pipe to be cleaned out by rods when necessary. Anti-syphonage pipes should be fixed from the drain side of the trap and carried through the outer wall with a flap valve at the end. Lavatory wastes should always discharge outside the building over a trapped gully or into the head of a waste pipe properly ventilated.

Baths.—These are made of porcelain, fireclay, enamelled iron, zinc, or copper. It is not an uncommon arrangement to provide a W.C. apparatus in the bath apartment, but this should never be done on account of the always more or less offensive odours emanating from such a fitting. Porcelain baths are practically indestructible, and are usually fixed in public establishments where they are subject to rough usage. They have the disadvantage of being very heavy, expensive, and require a large volume of hot water to heat the surface of the bath before it can

be used by the bather. In order to overcome this objection, a patent bath has been recently introduced which has a "flushing-rim." The roll of the bath is perforated at close intervals, so that immediately the hot water is turned on, a stream covers the whole of the inner surface of the bath, and this raises its temperature and at the same time cleanses the sides from any germs or

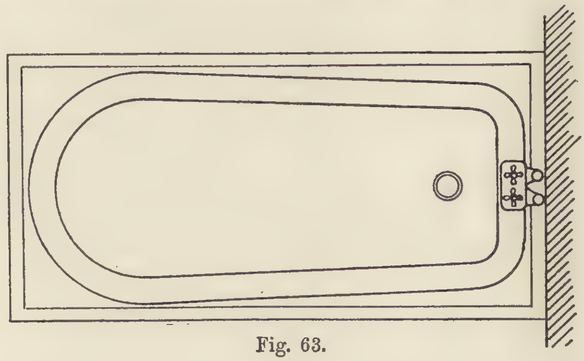


Fig. 63.

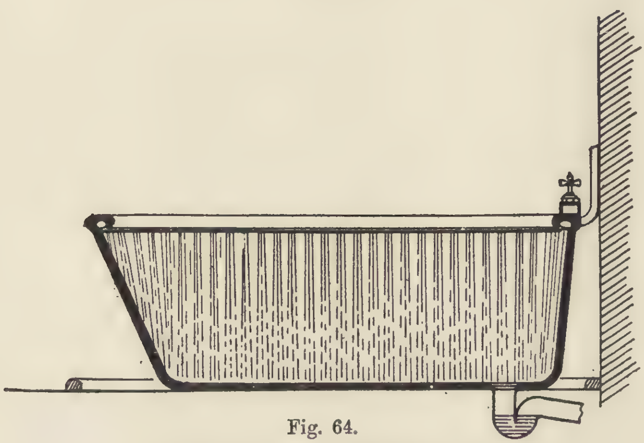


Fig. 64.
Plan and section of flushing-rim bath.

soapy deposit which may have collected on the surface. This bath is illustrated by Figs. 63 and 64. It is an excellent fitting for hospitals (where an equable temperature is essential), workhouses, and other institutions, where the bather may be either suffering from disease or be exceptionally dirty.

The type of bath most generally used in private houses is made of iron with the interior of vitreous enamel, and is generally known as the Roman pattern. This bath needs no enclosure, so

that the whole of the fitting, plumbing, and floor under is quite accessible for cleaning and repairs.

In selecting a bath, the following points should be observed: (1) the material of which the bath is made should be perfectly smooth and rendered water-tight; (2) no corners or angles should exist which might collect dirt or soapy deposit; (3) the whole of the fitting should be open and easily accessible for cleaning. The water-supply should be separate and disconnected from the drinking-water cistern. A good form of the Roman pattern bath

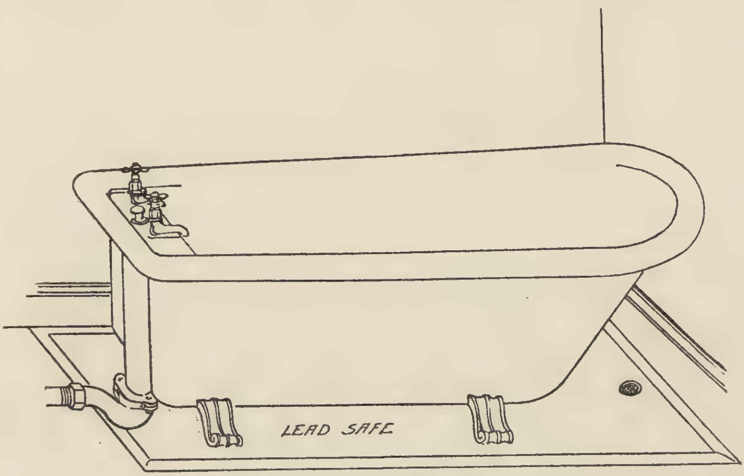


Fig. 65. Roman pattern bath.

is illustrated on Fig. 65, showing the hot and cold supplies. It will be seen that a large roll is provided at the top of the bath; but this is frequently supplemented by an additional top made in hard wood (mahogany, oak, or teak), so that the bather may be enabled to rest, either on entering or leaving the bath, on a material less cold than the iron roll.

The best form of waste is that of the "standing" pattern, which also acts as an overflow. A trap is fixed immediately under the waste, and the bath plug is raised by a lever or knob which can readily be removed for cleaning. As will be seen from the illustration, a lead safe with overflow is provided under the bath, and an anti-syphonage pipe from the drain side of the trap should be supplied.

In the more expensive form of fittings, the bath is often provided with a copper or zinc hood, by which means shower,

douche, needle, sitz, and other baths can be combined with the ordinary slipper bath.

In many old-fashioned baths the water-supply was made to enter through the upper part of the waste pipe at the bottom of the bath. This was a most objectionable arrangement, as when the clean water entered the bath by this means, it also conveyed the residue of soap and dirt left by the previous bathers.

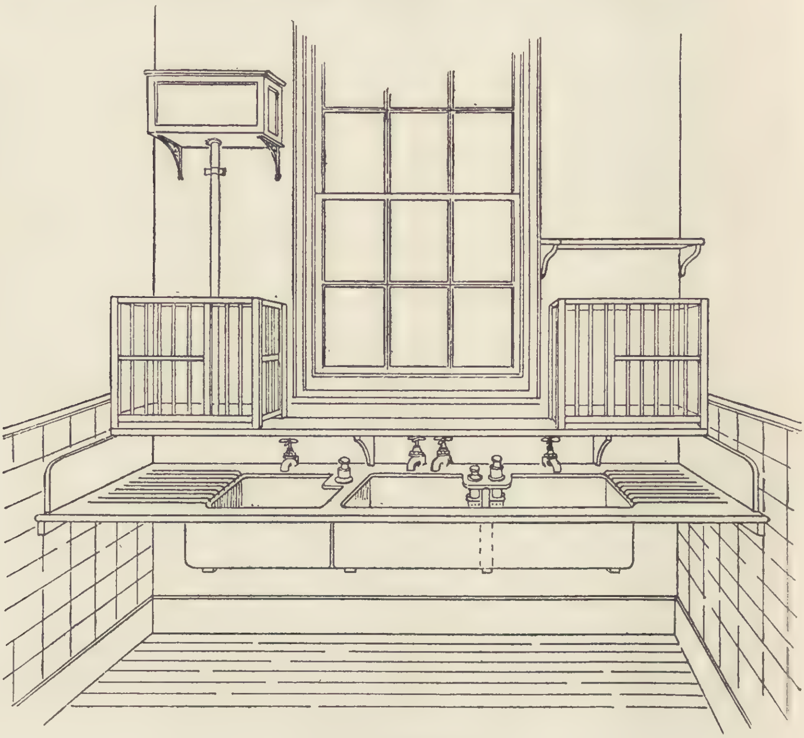


Fig. 66. Scullery sink.

Sinks.—In a building of the size illustrated, separate housemaids' slop sinks are not necessary, as the W.C. apparatus, provided with a porcelain slop sink for the prevention of splashing, can be utilised for this purpose. It is often advisable, however, in a private house to provide draw-off taps for washing purposes, with lead safes under. When such fittings are fixed, the writer has found it advisable to provide the smallest possible waste pipe. Servants have a regrettable tendency to use this sink for the reception of slops, and if the waste is made very

small, the time occupied in emptying a pail full of slops is so long that they use the W.C. apparatus in preference.

An ordinary scullery sink should have three divisions: one made in earthenware, for washing vegetables; the other two in teak, lined with copper or lead, and fitted with combined stand-up wastes and overflow. Draining boards with corrugations, and made in teak, should be provided as shown on Fig. 66. Cold water supplies should be provided for two of these divisions, whilst a hot and cold supply should be fixed to the third division, for washing crockery, etc. The waste should be properly trapped with screw cap for cleaning, as shown on Fig. 67. The waste of any sink from which greasy water is discharged should always be taken over a grease trap as shown on Fig. 68. When hot water charged with greasy matter is allowed to enter a drain over an

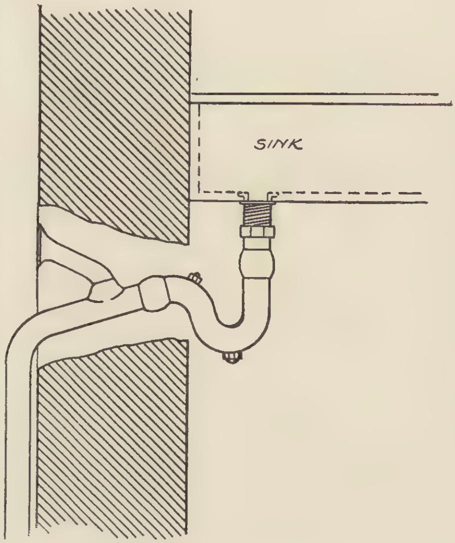


Fig. 67. Waste from sink.

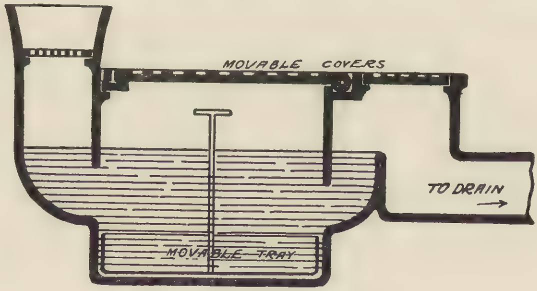


Fig. 68. Grease trap.

ordinary gully, the grease is apt to congeal and form solid matter, which eventually causes the drain to be stopped up. In hotels and other establishments where a large quantity of greasy water is discharged from the sinks, an automatic flushing tank is fixed

at the head of the drain, which discharges, say, 30 gallons of water at short intervals. By this means any grease which might cool and congeal is washed away into the drains before it has had time to adhere to the pipes and cause any stoppage. The grease trap illustrated is made with a receiver, at the bottom of which a tray is provided which can be lifted out and cleaned, so that the solid matter which has accumulated can be readily removed.

Rain-Water.—As before mentioned, the rain-water system is sometimes kept separate and distinct from the soil or foul drains, but this arrangement is seldom practicable in London, as the rain-water becomes so contaminated by soot and other impurities that a system of filtration would be necessary to render the water fit for use In a system of drainage applied to a London house, it is often advisable, however, to keep the least possible portion of the drainage subject to the discharge of foul matter. Whenever, therefore, the principal portion of any system is to receive rain-water only, a rain-water intercepter should be fixed at the lowest point. This intercepter is trapped on the sewer side, and has an open grating admitting fresh air; therefore the drains beyond it contain no sewer gas. Where a rain-water intercepter is fixed, it is therefore unnecessary to discharge the rain-water pipes over trapped gulleys. A good form of rain-water intercepter is shown on Fig. 48. When, however, rain-water drains are taken into the foul drains, it is necessary that they should discharge into trapped gulleys as shown on Fig. 69, which are very similar in construction to the rain-water intercepter.

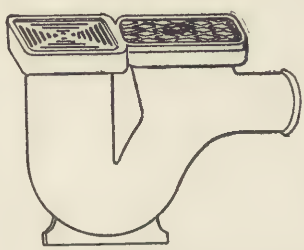


Fig. 69. Rain-water gulley with sweeping arm.

Rain-water pipes are made in cast iron or lead, and may be either square or circular in section, the latter being the better, as no angles are provided for deposit or corrosion. The outlets from the gutters discharge into open rain-waterheads at the top of the down pipes. Innumerable patterns are manufactured, many of excellent design. Rain-water pipes should never be fixed so as to touch the walls, but kept some 2 or 3 inches away from them in order to allow for repairs and painting. Lead rain-water pipes are joined by a wiped joint, and the iron pipes by the spigot end being inserted into a corresponding socket and the joint made

with molten lead. Lead down pipes are fixed to the walls by lead tacks soldered on to the pipes, and iron pipes by specially made cast-iron tacks. These are either made quite plain or ornamental, and many stock patterns of good design may be obtained.

CHAPTER V.

JOINERY.

General Remarks.—The joiner's work is distinguished from that of the carpenter, as being necessary, not for the stability of the building, but for its comfort as a habitation.

It includes making and fixing the doors, frames, sashes, and shutters, also wooden stairs, linings of all kinds, architraves, skirtings,[1] and floor boards.

These are all prepared in the workshop. A great deal at the present time is done by machinery, and the work of the joiner is daily becoming more confined to fixing only.

As the joiner's work is generally seen from a short distance, it must be fitted with care and exactness, and requires greater neatness and smoothness of finish than carpenters' work.

The thorough seasoning of the wood for joiners' work is of the first importance. Some particulars connected with the selection of timber for this purpose are given in the chapter on Timber, Part III.

All framing should be fitted and put together, and left as long as possible, before it is glued or wedged up, which should be done, if practicable, in summer when the wood is most dry.

Large pieces of timber should never be used in joinery.

The interior of all joints for outside work should be painted over with white lead ground in linseed oil; those for inside work glued.

Joiners' work is generally put together with the aid of a cramp; great care should, however, be taken in cramping and wedging up to prevent a strain upon the woodwork, which would lead eventually to cracking and distortion.

Beadings.—These are adopted generally for ornament, or in order that the opening of a joint caused by shrinkage may be hidden in the shadow cast by the projection of the bead.

[1] The consideration of linings, skirtings, architraves, and the grounds to which they are fixed, does not come within the limits of this chapter. Some of these are, however, shown in a few of the figures to make them more complete, and to save repeated illustrations when they are described in Chapter VI.

Beads are narrow, convex, plain mouldings;[1] in section generally parts of a circle.

When the bead is formed upon a board, in the substance of the wood itself, its upper surface being flush, or nearly so, with that of the board, it is said to be "*stuck*" (see Figs. 71, 72, and 73).

If the bead is formed in a separate strip, and nailed or bradded[2] to the board, it is described as "*laid in*" or "*planted*" (see Fig. 74).

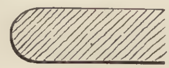


Fig. 70.

A Nosing or *Rounded Edge* is formed by rounding the edge of a piece of stuff, as shown in Fig. 70. It is frequently used for finishing off the edge of a projecting board, such as the tread of a step, a window board, etc.

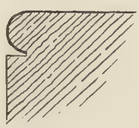


Fig. 71.

Fig. 72.

Fig. 73.

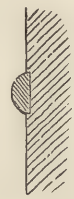


Fig. 74.

Quirked Bead.—In Fig. 71 the circular portion is the section of the bead, and the indentation at the side is called a "*quirk.*"

A Double-quirked Bead is one with a quirk on each side, as in Fig. 72. It is also known as a *Flush Bead,* because it is flush with the surface of the wood.

A Staff or Angle Bead is a double-quirked bead, formed upon an angle, as shown in Fig. 73. It is sometimes called a *Return Bead.*

A Cocked Bead is one which projects above the surface of the board. In order to avoid reducing the whole surface of the board, the bead may be made in a separate strip, and planted upon it, or laid in a shallow groove, as in Fig. 74.

A Cocked Bead and Fillet consists of a bead resting upon a flat strip or fillet slightly wider than itself, and planted on to the surface of the board, as in Fig. 117.

Reeding consists of parallel beads placed close together (see p. 78).

The Torus is a very large bead, surmounted by a flat strip or

[1] *Mouldings,* technically so called, do not fall within the limits of this chapter, but are described in Chapter VI.

[2] A *brad* is a particular form of nail, and is described in Part III.

"fillet," as shown in Fig. 75, also on a small scale on the upper edge of the skirting (*Sk*) in Fig. 137.

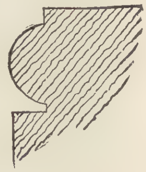


Fig. 75.

The torus is generally considered as a moulding, and is placed under that head in Chapter VI.

The distinction between a torus and a bead is that the former is always surmounted by a fillet.

The above-mentioned are the most simple beads in common use. There are several combinations of these, which cannot be further considered in this course.

The different positions in which beads are used are referred to farther on.

Shooting is simply making the edge of a board straight and smooth by planing off a shaving. A board is said to have its "edges shot" when both edges have been made smooth and true with a plane.

Rebating has already been described in Part I.

Chamfering is taking off the "arris" or sharp edge, so as to form a flat narrow surface down an angle, as shown on the style of the door, Fig. 76. This is frequently done for ornament, and also to render the angle less liable to injury.

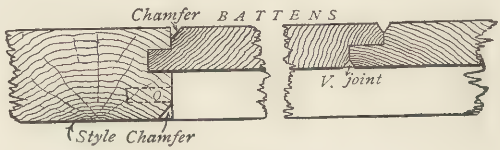


Fig. 76.

Chamfers are also often used for the same purpose as beads, especially on the edges of boards forming a close joint, so as not only to form an ornament, but also to hide the opening caused by shrinkage. An example of a chamfer thus applied is shown in the plan of the door, Fig. 76, between the style and the battens.

V-Joint is the angle formed by the meeting of chamfers on two adjacent edges, as in the boarding of the door above referred to, Fig. 76.

Stop Chamfer is one in which the chamfer is not carried to the extremity of the arris, but stopped and sloped, or curved up at the end till it dies away again into the square angle. Examples of this are seen in the framing of the door, Fig. 91, where the

chamfers are stopped about an inch short of the extremities of the rails and braces.

JOINTS.

When large surfaces have to be covered with boarding, the pieces should be as narrow as possible, in order that the shrinkage in each, and the consequent opening of the joints, may be reduced to a minimum.

Such shrinkage, however, there will inevitably be, and several arrangements are adopted for preventing cold air, dust, etc., from penetrating through the opening thus made between the boards, also in order to prevent the shrinkage from injuring the appearance of the joints; and further, to counteract the tendency of an ill-seasoned board to warp,[1] twist, and raise its edges above the general plane of the surface.

Several joints of this nature have already been described in the section on Floors (see Part I.)

Plain or Butt Joints are explained and figured at p. 133, Part I. The opening caused by the shrinkage of such a joint is, of course, very apparent; and there is nothing to prevent a board from twisting its edges above the surface.

Dowelled Joint is shown in Fig. 307, Part I. The shrinkage in this joint is visible, and causes an opening, but the dowels keep the surfaces of the boards in a true plane.

Grooved and Tongued Joint is explained and figured at p. 134, Part I.

Match Boarding consists of boards put together with the last-mentioned joint, one edge of each board being beaded, as in Fig. 778. It is so called because the groove is formed with one plane and the tongue with another to match or correspond, so as to fit the groove.

Plough Grooving is so called because the groove is formed with a peculiar plane called a "plough."

Cross Grooving is the same as the above, but that the groove is cut across the grain of the wood.

Slip Feathers are detached tongues or strips of iron or of hard wood cut across the grain for strength; in using them both

[1] Sc. for warped is *Thrawn.*

boards have to be grooved and the tongue inserted, as shown in Fig. 305, Part I. Tongues are generally of hoop iron, and slip feathers of wood cut across the grain.

If a slip feather is cut with the grain—that is, if the grain runs parallel to the length of the slip—and it is glued tight into the grooves, it is very liable to split longitudinally when the boards it unites commence to shrink. This cannot happen with a *cross tongue*—that is one cut across the grain.

Ploughed and Tongued—GROOVED AND FEATHERED—are terms applied to boarding prepared with tongues or slip feathers.

Dovetailed Slip Feathers are of a double dovetail shape in section (see Fig. 77), and must of course be pushed into position endways from the extremity of the boards. They are very seldom used.

Fig. 77.

Rebated Joints.—REBATED AND FILLETED JOINTS, AND FILLISTERED JOINTS, are all described at pages 133, 134, Part I., in connection with floor boards, for which they are most adapted.

In all the above (except the dowelled and butt joints) it will be seen that any opening caused by shrinkage of the boards will be covered by the tongue, feather, or fillet, or (in the case of the rebated, and of the fillistered joint) by the projection below of the adjacent board.

In each of the joints illustrated in Figs. 302, 303, 306, Part I., part of the width of the board itself is taken up in forming the joint, so that a greater quantity of boarding is required to cover a given surface than if joints with detached tongues, fillets, or dowels are used, as in Figs. 304, 305, 307 of Part I.

There are several elaborate forms of joint, consisting of double grooves and tongues of different lengths, combinations of the above, but they are too complicated for use in practice.

Beaded Joints.—It has been said above that a certain amount of shrinking in the boards of ordinary work is inevitable.

The actual passage of air and dust through the openings thus formed may be prevented by the various forms of tongued, feathered, and similar joints, already described; but in many positions, such as in linings of walls, in doors, etc., the unsightly appearance presented by the gaping joints between the boards would be objectionable.

In such cases, to hide the openings caused by shrinkage, a quirked bead is "stuck" upon one angle of each board, in order

that the opening of the joint may be hidden in its shadow, or look merely like another quirk on the opposite side.

Fig. 78.

Fig. 78 shows the bead as applied to a grooved and tongued joint or *match-boarding*; it may be used in the same way for rebated or plain butt joints.

Dovetail Joints are chiefly used to connect boards meeting at an angle.

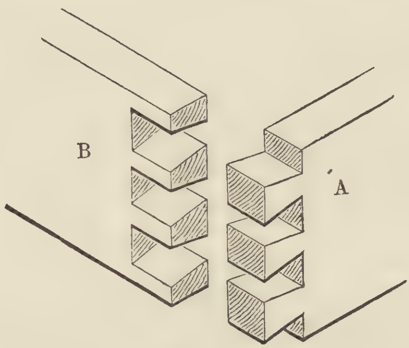


Fig. 79.

Common Dovetail Joint.—In this the edge of each board is cut into a series of alternate projections and indentations, known as the "pins" and "sockets," which fit one another and form the joint. In Fig. 79 the pins are formed upon A and the sockets on B.

The ends of the projections or dovetails show on each side of the angle formed by the boards when they are put together.

In some cases the spaces between the pins are only equal in size to the pins themselves, as shown in Fig. 79. This makes the strongest joint, but very frequently the pins are placed much farther apart.

The angle or bevel of the sides of the dovetail should vary according to the nature of the wood in which it is formed. A dovetail in hard wood should have more splay or bevel than one in soft wood.

The common dovetail is chiefly used for the angles of drawers and superior boxes, where they are generally not seen, but it is also occasionally adopted in building for securing the angles of skirtings, and for casings of a superior description.

Mitred, or Secret, Dovetails and Lap Dovetails are modifications of the above, used chiefly by cabinetmakers; they will be described in Chapter VI.

Mortise and Tenon Joints, used for framing in joiners' work, resemble those in carpentry, but are much smaller, and require to

be made with greater care and exactness, so that they may fit smoothly in all their parts.

The thickness of the tenon varies from $\frac{1}{3}$ to $\frac{1}{4}$ of that of the framing, care being taken to leave sufficient substance in the cheeks of the mortise. The width of the tenon should not be more than 5 times its thickness, or it will be liable to bend.

HAUNCHING a tenon is the cutting away a part of it, so as to leave a piece (*h*, projecting to a distance of only $\frac{1}{2}$ inch or 1 inch) between it and the outer edge of the rail on which it is formed. This haunch gives the tenon great lateral strength, and saves cutting so large a mortise hole. The haunch and the mortise to receive it may extend to the outer edge of the pieces framed together.

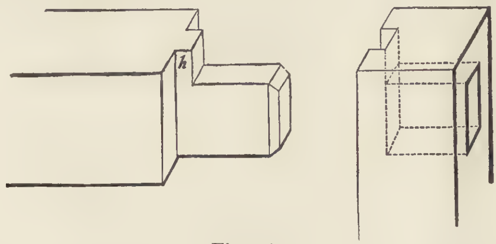


Fig. 80

Examples of haunching are shown in the rails of the door, Figs. 104, 108.

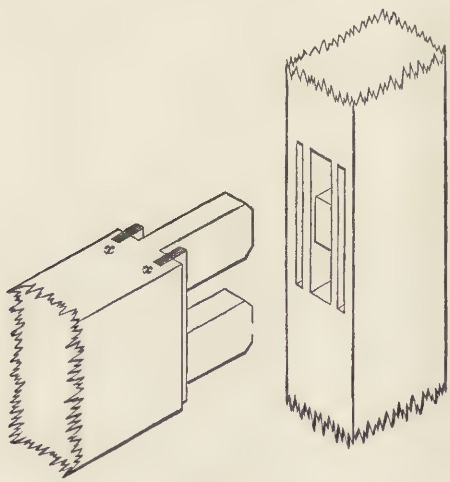


Fig. 81.

DOUBLE TENONS are formed on very wide rails in framing. They prevent the rail from twisting, do not shrink so much as a

single wide tenon, and do not require so large a mortise, which latter tends to weaken the framing in which it is formed. As the wood between the roots of the tenons shrinks more *across* the grain than the wood between the mortises does *with* the grain, the result often is to split the rail. The space between the tenons is haunched, as will be seen in Fig. 81 by examining the mortise.

An example of such haunching is also shown in the lock rail of the doors, Figs. 104, 108.

Occasionally two tenons side by side in the thickness of the framing are advisable, as, for example, in the lock rail of a thick door, to receive a mortise lock (see M, Fig. 104); but where a single tenon with cross tongues can be used, it is stronger and more easily fitted.

Stump Tenons or Stub Tenons are required if the frame be very thick as well as wide. They are tongues or projections left in the wood on each side of the tenon.

Slip feathers or cross tongues inserted in ploughed grooves are frequently used for the same purpose, as shown at $x\,x$ in Fig. 81.

Housing consists in letting the whole end of one piece of timber for a short distance into another (see Part I.). The recess formed in one piece to receive the end of the other piece is called the *housing*, and one piece is said to be *housed* into the other. Fig. 82 shows the *housings* formed in the string board of a stair to receive the ends of the steps which are *housed* into it. (See Chapter VII.)

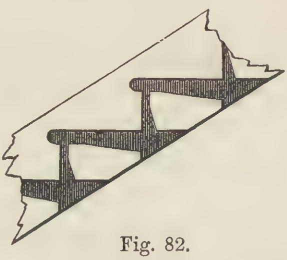


Fig. 82.

Mitred Joint.—When two pieces of wood have to be joined at an angle, the joint if not too long may be *mitred* as in Fig. 83, that is, the two pieces are cut to a level so that the plane of the joint bisects the angle. This is called the "mitre."

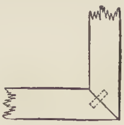


Fig. 83.

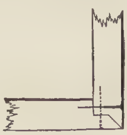


Fig. 84.

This joint depends entirely upon the glue unless strengthened by a slip feather dotted in Fig. 83.

Fig. 84 is a modification of this joint which can be nailed both ways and is good for exterior angles. Other modifications are shown in Chapter VI.

Scribing is cutting the edge of a board to fit an irregular surface; thus the skirting in Fig. 137, if not tongued into the floor (as shown), would be scribed at the bottom to fit the boards supposing they were uneven.

FRAMING.

Frames in joinery consist of narrow pieces of wood connected by mortise and tenon joints, and grooved on the inside to receive boards, which fill up the openings in the framing.[1]

In every frame the vertical pieces are called "*styles*"[2] (S S, Fig. 85), the horizontal pieces *rails* (R R). These constitute the framing itself, and in the example shown are filled in with panels (P P).

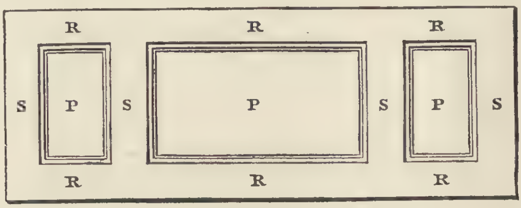


Fig. 85.

The pieces of wood forming a frame should be narrow, so as to be affected as little as possible by shrinking under atmospheric influence.

The inner edges of the styles and rails are grooved to the depth of about $\frac{1}{2}$ inch to receive the panels, which should fit so tightly as not to rattle, and yet should be free to contract.

Panelling.—*General Remarks.*—The boarding which fills in each opening of any piece of framing is called a *panel.*

Boards, except of American pine, can seldom be obtained of sufficient width to form panels in one piece, on account of shakes and other defects.

A joint down the panel is therefore generally necessary; this should, if the stuff is thick enough, be ploughed, and a slip feather be glued into it, which keeps the surface of the panel in a true plane and holds the joint together, so that when the panel shrinks it comes slightly away from the grooves in the styles, as it is intended to do.

The pieces thus used to form panels should be reversed alternately, so that the grain may run in opposite directions.

---

[1] Sc. for Framed is *Bound.*

[2] Known also as *Muntins.*

A piece of strong canvas glued over the back of a panel will assist in keeping it together.

There are several forms of panels, known by technical names, depending upon the manner in which they are respectively constructed and ornamented.

The different kinds of panels now to be described are illustrated in Figs. 93 to 103, and in Plate I. These figures are elevations and sections of doors, but the same constructions are used for panelling of all descriptions.

SQUARE AND FLAT PANELS [2] are those in which the boards are of the same thickness throughout, thinner than the frame, sunk square below its surface, and not ornamented by beads or mouldings.[1] The panels marked A and B in Figs. 93 and 97 are "square and flat" [2] or "square" on both sides.

MOULDED AND FLAT,[2] or SQUARE AND FLAT AND MOULDED, or MOULDED AND SQUARE.—When the edge of the panel, close to the framing, is ornamented by a moulding either "planted" or "stuck" on to the inner edge of the frame, it is designated as "moulded," or "moulded and flat." [2] Panel F, Fig. 101, is moulded on both sides, and panel E moulded in front only.

FLUSH PANELS have their surface "flush," or in the same plane with the surface of the frame. A panel may be flush on one or both sides.

In nearly all forms of flush panelling the edges of either the frame or panel are ornamented by a bead, chamfer, groove, or moulding, to cast a shadow and conceal the shrinkage.

If required to be flush on both sides, the back is generally filled in with a separate solid piece, or with diagonal battens crossing their grain with that of the front panel.

D, Fig. 98, is a panel flush on both sides, while C is flush in front only.

SOLID PANELS are those in which the panel is in one piece, of the same thickness as the frame, and flush on both sides with its surface, like panel D, Fig. 98.

BEAD-FLUSH panels have a bead all round close to the inner edge of the framing, as shown in the panels I K, Fig. 96.

[1] Mouldings form part of advanced joinery, and are more fully described in Chapter VI.

[2] The words "and flat" (originally used to prevent the panel from being roughly bevelled off toward the edges to fit the groove) are now generally omitted, and a panel is described as "framed square" or "moulded," it being understood that the surface is flat and the panel of equal thickness throughout.

The bead in this case is sometimes "stuck" on the styles and rails, as shown in Figs. 114, 115.

If the framing is thin and the quirk of the bead deep, it cuts nearly through to the groove and is a source of weakness, so much so, that the swelling of the panel sometimes presses the bead off; moreover, when the framing shrinks, the mitred angle of the bead (at the corners of the panel) opens, and sticking the bead on the framing itself entails extra trouble in putting it together.

In modern practice, however, the vertical beads are generally "stuck" (with the grain) on the panels, and as the horizontal beads cannot easily be formed across the grain, sunk rebates are cut for them on the panels close to the edges of the rails, and beads on separate strips bradded into the groove thus formed. Sometimes these strips become curved when the panel shrinks, and are apt to fall out; and as they shrink less in length (along the grain) than the panel does in width (across the grain) they cause it to split; however, as this plan is more economical than the other, it is commonly adopted.

The detached bead just described is illustrated in Fig. 103, which is an enlarged vertical section of the lower part of the lock rail and upper part of the bottom panels of Fig. 96. The horizontal section of a bead-flush panel formed in this way is similar to that of bead-butt shown in Fig. 98.

Bead-butt panel is a modification of the last, used chiefly in inferior work.

In this case the beads are formed only along the sides of the panel, *with* the grain of the wood, and always "stuck" on the panel itself, as shown in elevation in Fig. 93, and in plan in Fig. 98, the panels being marked C D in both figures.

Reed-flush panel is one covered with parallel semi-cylindrical beads, close together, either "stuck" in the substance of the panel, if they run with the grain, or "planted" on if they run across the grain.

Grooved Panel.—In this a groove is formed around the outside edge of the panel, close to the framing, causing a dark shadow which answers the same purpose as a bead.

Chamfered (or V-jointed) Panel is ornamented by chamfers run down the edges of the framing and of the panel, as shown in the back of the panel marked D in Fig. 98 (see also Fig. 76).

Raised Panel[1] has the surface nearly flush with the frame in the centre, but recessed back at the sides where it meets the frame.

The rising of the panel may either be left square, as at H, or enriched by a moulding, as in panel G, Fig. 102. See also Figs. 105, 108, 113, and 124.

The frame also is frequently ornamented with mouldings, either "stuck," as in Fig. 124, or planted on, as in Figs. 102, 117.

Panelling is often enriched with mouldings of different descriptions; these are either "stuck" on the frame, or more frequently laid or "planted" in in strips bradded on to its inner side.

Sometimes, especially in doors, the panelling is intended to have a better appearance on one side than the other. It is then formed differently on the two sides, and named accordingly.

For example, in Fig. 101, the panel E is "moulded in front with square back."

The panel F is "moulded on both sides."

In Fig. 98, panel D has a "bead-flush front, with chamfered and flush back."

Panel G, Fig. 102, is a "moulded and raised panel with moulded rising on both sides"; while H is a "raised panel with square rising in front, and square back."

Bolection Mouldings.—Large doors are frequently finished with *Bolection Mouldings*, which project beyond the framing as in the lowest panel of Fig. 118, Plate II. See also panel F, Plate I.

DOORS.

Internal doors should be at least 2 feet 9 inches wide, and 6 feet 6 inches high. A usual opening is 3 feet, or 3 feet 6 inches.

A common rule for proportioning the size of doors is to add 4 feet to the width to obtain the height. Thus a door 2 feet 9 inches would be 6 feet 9 inches high. Very large rooms are sometimes connected or thrown into one by doors 8 feet or more in width, and 8 feet to 10 feet high.

Vitruvius gives as a rule for internal doors that their height, to give the best architectural effect, should be $\frac{4}{7}$ that of the room.

Entrance doors vary in width from 3 feet to 5 feet.

When a door is more than 3 feet 6 inches wide it should as a rule be hung in two halves ("*hung folding*"), by which arrange-

[1] Sc. *Fielded panel.*

ment it requires less space into which to open, and the leaves are lighter.

Doors should, as a rule, open inwards *from* a person entering the room, and they should be so placed as to conceal as much as possible of the room when they are partly open.

Doors are described as right or left handed according to the direction in which they open. A door which opens inward towards the right, as in Fig. 89, is called a "right-handed" door, while one opening inwards towards the left, as in Fig. 124, is a left-handed door. Locks are made right and left handed to suit the arrangement of the doors.

The following letters are used to mark the parts mentioned, in the figures of this section relating to doors:—

Architrave	A	Ledges	*ledge*
Brace	*br*	Lock	L
Frame	F	Rails	R
Ground	*g*	Styles	S
Hinge	*h*	Wood Brick	WB
Latch	*l*	,, Plug	*wp*

Doors receive their distinctive names according to the nature of their construction.

A **Ledged Door** [1] is the simplest kind of door made, and is used only for temporary or inferior purposes.

The very commonest consist of vertical boards butted against one another, and connected by two or three horizontal pieces called "*ledges*" [2] nailed across the back.

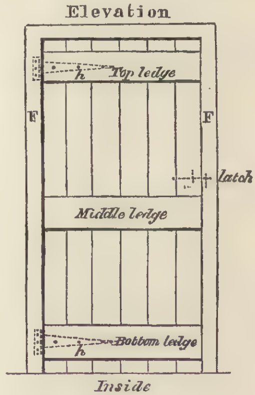


Fig. 86. *Ledged Door.*

In ledged doors of a better class the boards are grooved or ploughed and tongued together, sometimes united by rebated joints, and nearly always beaded or chamfered.[3]

The ledges should be fixed on the inside of the door, which is, in Figs. 86, 87, shown to open outwards. The rebate in the frame is here shown of a depth only equal to the thickness of the boards or door itself, the ledges being cut off at the ends so as not to fit into the frame.

In some cases, however, the ledges are made of a length equal to the full width of the door, and recesses are cut out in the frame beyond the rebate to receive them where they occur.

[1] Sc. *Barred Door.* [2] Sc. *Bars* or *Cross Bars.*

[3] A "*Proper-Ledged Door*" is one in which the boarding is wrought, ploughed, tongued, and beaded. The term is becoming obsolete.

The arrangement here shown would be objectionable for a door of any importance, for even when locked it can at any time be opened by unscrewing the hinges from the outside.

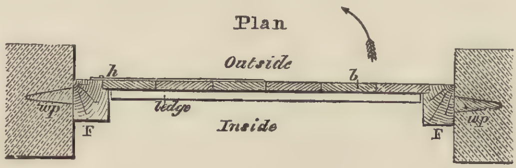


Fig. 87. *Ledged Door.*

If such a door be required to be very secure, it should have hinges on the inside,[1] as in Figs. 88, 89, or be hung with external hook and eye hinges fixed with bolts and nuts on the inside (see Figs. 90, 92), which cannot be removed when the door is locked.

A Ledged and Braced Door has braces diagonally across the back in addition to the horizontal ledges, as shown in Fig. 88.

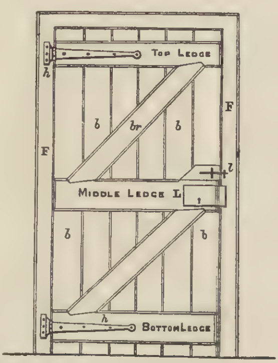


Fig. 88. *Inside Elevation of Ledged and Braced Door.*

The ledges and braces shown in this figure are bevelled or beaded, and the boarding is ploughed, tongued, and beaded on both sides.

The braces should be fixed so as to incline downwards toward the side on which the door is hung.

The beads on the inside of the door are often omitted, but are just as much required there as on the outside, to conceal the joints when the boards shrink.

The frame generally has a bead run round its inner edge to conceal the joints between it and the door.

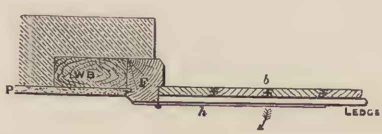


Fig. 89.

The door illustrated in Figs. 88, 89 is arranged to open

[1] The hinges and latch of the common ledged door are dotted in Fig. 86 to show that they are on the outside.

inwards, the rebate in the frame being made of a depth equal to the united thicknesses of the boarding and ledges, as shown in Fig. 89.

Sometimes the frame is rebated to a depth only sufficient to receive the boarding alone, in which case the hinges are fixed upon blocks attached to the frame, the surfaces of the blocks being flush with those of the ledges.

A Framed and Braced Door.[1]—This door consists of a frame strengthened by a middle or lock rail and diagonal braces, the edges of which are stop-chamfered to give them a light appearance, as shown in the internal elevation Fig. 91.

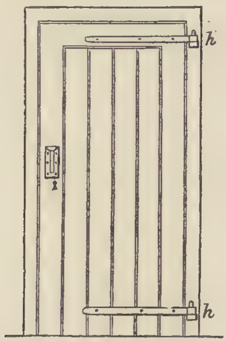


Fig. 90. *External Elevation.*

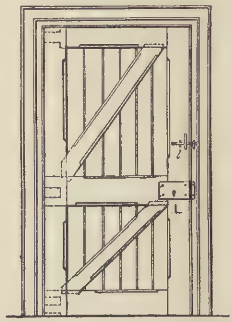


Fig. 91. *Internal Elevation.*

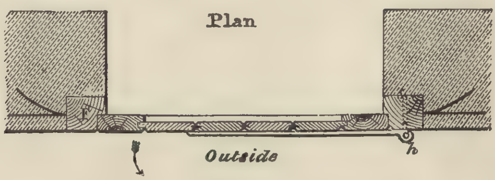


Fig. 92. *Framed and Braced Door.*

The ends of the braces are tenoned into the styles and rails as shown; the upper ends are frequently made to abut partially upon the styles, but this has a tendency to force them off the rails. The braces should therefore be connected at the upper end with the rails only, as shown in Fig. 91. The lower ends may abut partially upon the hanging style, and they are sometimes kept entirely clear of the rails.

The braces and lock rails are thinner than the remainder of the framing by the substance of the boarding, which lies against them and is nailed to them.

[1] Sometimes called Framed, Ledged, and Braced.

In external doors the bottom rail is generally covered by the boarding, so as to be invisible from the outside. This enables the rain to get clear away, instead of being caught by the bottom rail.

In Fig. 91 the framing is stop-chamfered, and the boarding ploughed, tongued, and V-jointed on both sides. The door opens outwards, and is hung with hook and eye hinges. An enlarged section of part of this door is given in Fig. 76, p. 70.

A Framed and Ledged Door is like that shown in Fig. 91, without the braces.

Panelled Doors consist of a framework of narrow pieces of equal thickness put together with mortise and tenon joints, and grooved on the inside edges to receive the panels.

Fig. 93 shows the elevation of a four-panelled door, and Fig. 96 that of a door with six panels.

Figs. 97, 98, 101, 102 are horizontal sections taken through the panels identified in elevation by the same letters. Figs. 99, 100 are parts of Fig. 98 enlarged.

The horizontal bars of the framing are called "*Rails*," and the vertical bars "*Styles*." The centre style is also called a "*Munting*."[1]

In a six-panelled door the uppermost horizontal bar is the *Top Rail*, the next below is the *Frieze Rail*, the next the *Lock* (or *Middle*) *Rail*,[2] and the lowest the *Bottom Rail*.[3]

The two highest panels are the *Frieze Panels*, the two next the *Middle Panels*, and the lowest the *Bottom* or *Lower Panels*.

The *Top Rail* and *Frieze Rail* are generally of the same width as the *Styles* and *Munting* (about $4\frac{1}{2}$ inches); the *Lock* and *Bottom Rails* are about twice, or frequently rather more than twice, as wide as the others.

The centre of the lock rail should be about 2 feet 6 inches above the ground, so that the lock may be at a convenient height for the hand.

In a four-panelled door there are no *Frieze Panels*. The uppermost panels are the *Upper* or *Top Panels*. The *Frieze Rail* is also omitted, the other parts being named in the same way as in the six-panelled door.

The number, relative size, form, and position of the panels is varied in different doors according to taste and to the purpose for which they are intended.

[1] Or *Muntin*, or *Mounting*. Sc. *Mounter*. [2] Sc. *Belt Rail*. [3] Sc. *Sole Rail*.

Scale $\frac{1}{2}''=1$ *ft.*

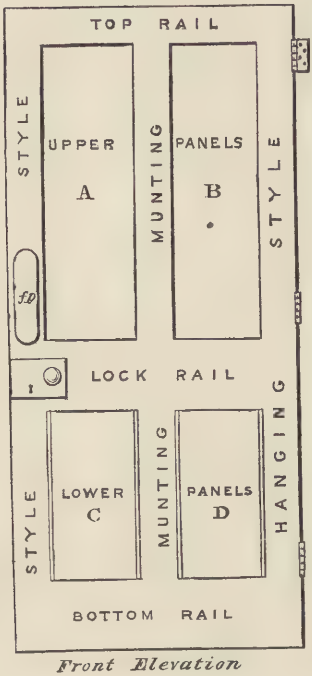


Fig. 93.

Fig. 94.

Fig. 95.

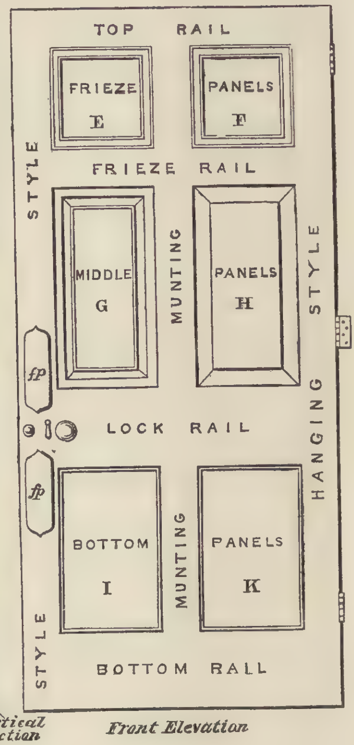


Fig. 96.

Horizontal Sections (*Scale* $1''=1$ *ft.*)

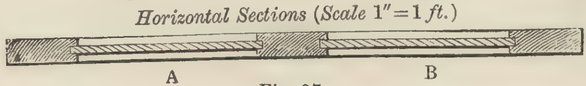


Fig. 97.

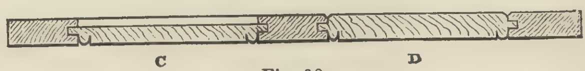


Fig. 98.

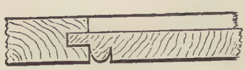


Fig. 99.

Fig. 100.

Fig. 103.

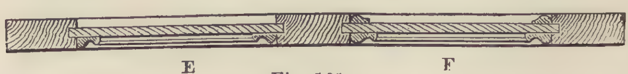


Fig. 101.

Fig. 102.[1]

[1] It will be understood with reference to the above figures and those on Plate I.

In six-panelled doors the frieze panels are often of oblong form, being wider than their height, and the four lower panels nearly equal in size to one another (see Fig. 104). Sometimes the small panels are placed in the middle of the door.

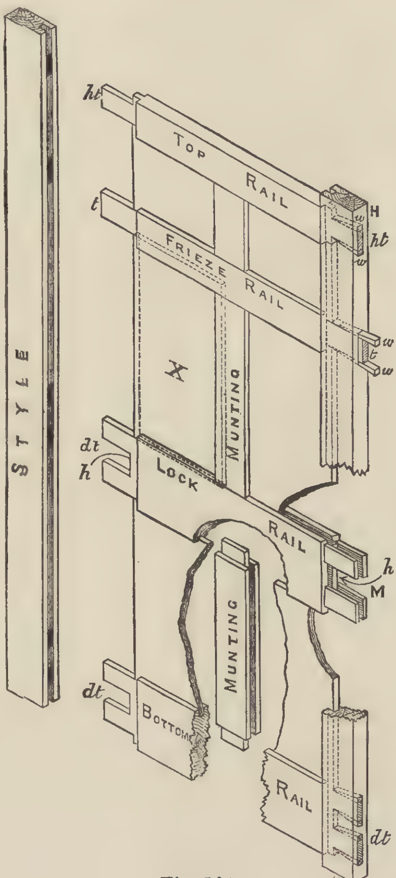


Fig. 104.

Method of putting a Door together.—Fig. 104 shows the method of putting together a "*six-panelled square-framed door.*" A comparison of this figure with the horizontal section of a square-framed panelled door given in Fig. 97, and with Plate

that opposite panels on the same side of a door are never made to differ from one another as G H do. They are shown so here and in Plate I. in order to include several different kinds of panels in one illustration.

I., will clearly show its construction. The mouldings are omitted in Fig. 104.

The figure shows one style of the door detached, the other is in position, and supposed to be transparent, in order to show the construction of the tenons which fit into it.

The rails and styles are continuous throughout their length; but the munting is divided into three parts tenoned in between the rails. A portion of the door is broken away to show the construction of the munting between the bottom panels.

It will be noticed that the styles are longer than the height of the door, have projecting "*horns*" (HH) which extend above and below the bottom rails. These horns are left until the door is wedged up, in order that there may be sufficient substance to resist the pressure of the wedges, which would otherwise, pressing in the direction of the grain, force out the wood beyond the mortise in the style, and destroy the joint.

These horns are, of course, removed when the door is finished and cleaned off ready for hanging.

The ends of the rails are formed with tenons of different kinds, as shown in Fig. 104. These fit into mortises in the styles, and are there secured by wedges.

The top rail has a single haunched tenon at each end, the frieze rail a common tenon at each end, and the bottom rail a double tenon at each end.

The lock rail is provided at *dt* with a double tenon, strengthened by a haunch (*h*) between them; thus the necessity of a very large mortise (which would cut the style nearly in two) is avoided. When an ordinary mortise lock is used for a thick door, that end of the rail in which the lock is to be fixed should be provided with four tenons, as shown at M; between these there is room for the lock, which can be inserted without interfering with the tenons. The construction of this joint is shown in the figure, a portion of the style having been broken away in order to show the tenons more clearly.

The common practice, however, is to make an ordinary double tenon in the centre of the framing, like that at *dt*, the result being that the formation of the mortise for the lock cuts away portions of the tenons, and weakens the joint. Small mortise locks are made to obviate this difficulty.

The inside edges of the styles, munting, and rails are grooved down the centre about $\frac{1}{2}$ inch deep and for $\frac{1}{3}$ of their width to

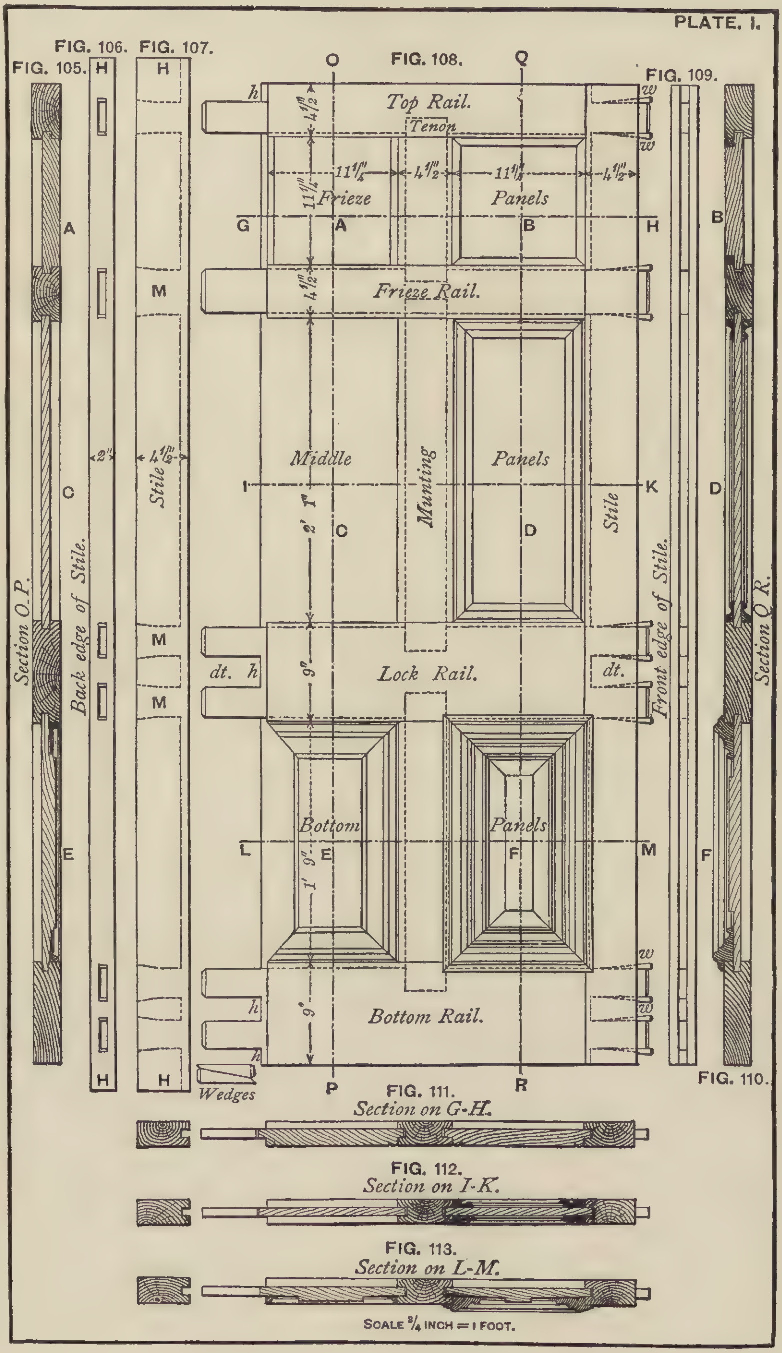


PLATE. I.
FIG. 105.
FIG. 106.
FIG. 107.
FIG. 108.
FIG. 109.
FIG. 110.
Section O.P.
Back edge of Stile.
Stile
Top Rail.
Tenon
Frieze
Panels
Frieze Rail.
Middle
Munting
Stile
Lock Rail.
Bottom
Panels
Bottom Rail.
Front edge of Stile.
Section Q.R.
Wedges
dt.
FIG. 111.
Section on G-H.
FIG. 112.
Section on I-K.
FIG. 113.
Section on L-M.
SCALE 3/4 INCH = 1 FOOT.

receive the panels. The edge of the panel (X, Fig. 104) is shown in dotted lines.

The door having been made, the tenons carefully fitted to the mortises, etc., it is put together without any fastening, and left until immediately before it is required to be fixed, in order that it may have as long a time as possible to season.

Before being fixed the door is taken to pieces, the mortises cleared out, the tenons covered with glue, the styles, munting, and rails tenoned into each other, and the panels inserted. The deal wedges (*w w*) are then dipped in glue and driven in as shown, on each side of the tenons, the flat part of the wedge being next to the tenon.

In Fig. 104 the wedges securing the frieze rail are shown as originally fixed. Those for the top and bottom rails have been cut off flush with the style; this is shown so for the sake of illustration, but in practice it is not done until all the parts of the door are put together and "*wedged up.*"

The door should then be laid upon a flat firm surface till the glue is dry.

In high-class work with hard woods to be left unpainted the tenons of the rails and the mortises to receive them are stopped short of the edge of the styles so that they may not show. The tenons may be secured by fox-wedging, but when they are well fitted this is not necessary, thin glue being sufficient to hold the work.[1]

Plate I.[1] gives elevations and sections of another six-panelled door, with different kinds of panels and one style removed. It requires no further description after that already given of Fig. 104.

The different descriptions of Panelled Doors are distinguished by technical names expressing their thickness, the number of panels they contain, and the kind of panelling.

The doors in Figs. 93 to 103, and that in Plate I., are each shown with two or three different kinds of panels, but it will be understood that this is only to save repeated illustrations. As a rule,[2] all the panels on the same side of a door are of the same construction, though frequently those on the front are more ornamented than those on the back of the door.

By combining the information contained in the figures, the

[1] *S.M.E. Course.*

[2] There are, however, exceptions to this rule, as, for example, in Fig. 115, where the upper panels are moulded both sides, but the lower panels have a bead-flush front for strength.

student will be able to draw several varieties of doors. The names of some of these, and a reference to the figures from which they may be constructed, is now given, and is arranged for convenience in a tabular form.

1 Description of Door.	2 Arrangement and Size of Panels.	3 Section of Panels.	4 Appearance of Panels in Elevation of *Front*, Size and Arrangement being as described in Col. 2.
1½-inch Four-panelled—			
Square framed . .	As in Fig. 93	Like AB, Fig. 97	Like AB, Fig. 93
Bead butt and square .	,, ,, 93	,, C, ,, 98	,, CD, ,, 93
Filled in solid, bead butt, and back chamfered flush	,, ,, 93	,, D, ,, 98	,, CD, ,, 93
2-inch Six-panelled—			
Moulded and square .	,, ,, 96	,, E, ,, 101	,, EF, ,, 96
Moulded on both sides .	,, ,, 96	,, F, ,, 101	,, EF, ,, 96
Bead flush and square .	,, ,, 96	,, C, ,, 98 and ,, 103	,, IK, ,, 96
Raised and moulded panel with moulded rising both sides . . .	,, ,, 96	,, G, ,, 102	,, G, ,, 96
Raised panel and square rising, back square .	,, ,, 96	,, H, ,, 102	,, H, ,, 96
2-inch Six-panelled door hung folding, four upper panels moulded both sides, bottom panels bead flush and moulded back . .	,, ,, 116	Figs. 114, 115	Two lowest panels like IK, Fig. 96; the other panels like those in Fig. 116.

A Two-leaved or Folding Door is hung in two flaps, one on each side of the opening.

Figs. 114, 115, 116 show respectively the plan, a vertical section through the panels, and the interior elevation, of a six-panelled outer door—hung folding—with a fanlight over it.

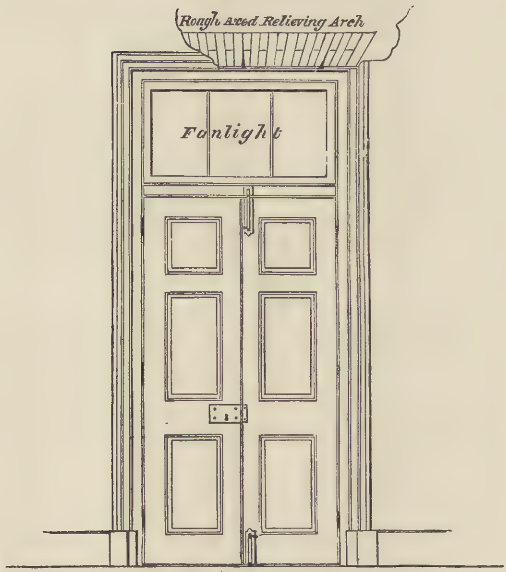
The piece framed in between the door-posts, separating the fan-light from the door, is called a *Transom*. Its upper surface is weathered outwards, and the joint between it and the fan-light is sometimes secured by a water bar or stepped so as to prevent the entrance of wet.

The four upper panels of the door are moulded on both sides, while the two lower panels are made bead-flush on the outside, so that they may be thicker and stronger.

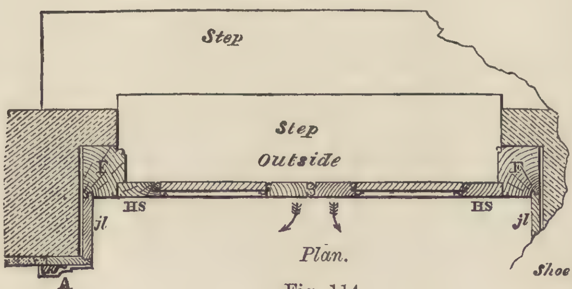
In the example given the wood linings are secured to plugs let into a rough axed arch, shown in section, Fig. 115, and partly in elevation (Fig. 116), some of the plaster, etc., having been removed so as to expose it. A concrete lintel or wood lintel with relieving

Fig. 117.

Fig. 116.



Interior Elevation *Scale* $\frac{1}{4}'' = 1$ *ft.*

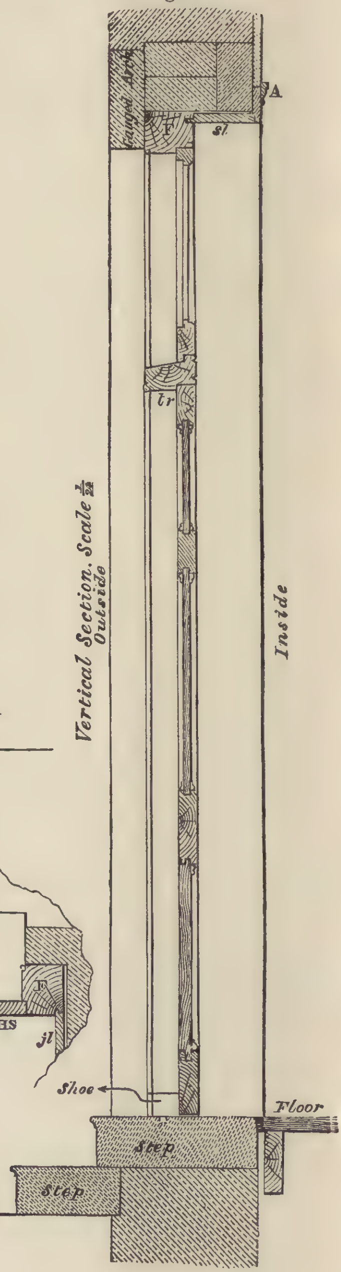


Plan.

Fig. 114.

Scale $\frac{1}{2}'' = 1$ *ft.*

Fig. 115.



arch may be used instead of the rough axed arch to support the wall above the door.

In this illustration the joints and soffits of the opening are covered by wood linings, the description of which will be found in Chapter VI., pp. 129 to 134. When there are no linings the frame is grooved to receive the plastering of the wall, as in Figs. 89, 135.

To prevent wet from getting in under the door, the step should be well weathered and not too wide. The riser of the upper step in Fig. 115 might be flush with the face of the door frame. In many cases a weather-board, such as that shown in Fig. 144, is added.

Another plan is to form a recess about $1\frac{1}{4}$ inch deep in the step and floor, close to the inside of the door, to receive a door mat; while a narrow groove may be cut in the step close to the door, with outlet graded to throw the water off. All very exposed external doors should be protected by porches.

The joint formed by the meeting of the leaves may either be simply rebated and beaded, as shown in Fig. 114, or it may be further secured by a detached "cocked bead and fillet" planted on each side, as in Fig. 117.

Double-Margined Doors are hung in one flap, but have a bead run down the centre, so that they may look like doors hung "folding."

Sash Doors have their upper portion glazed. The styles of the glazed portion are often made narrower than those of the panels below, and are then described as "*diminished styles.*" In this case the joints between the ends of the lock rail and the styles are cut obliquely instead of being vertical, by which more light is obtained, and the sash portion of the door is given a lighter appearance.

Plate II. gives a part elevation and details of a sash door with styles, diminished at X. When the glazed portion of the door is divided into smaller panes the styles are often considerably diminished so as to look like those of a sash.

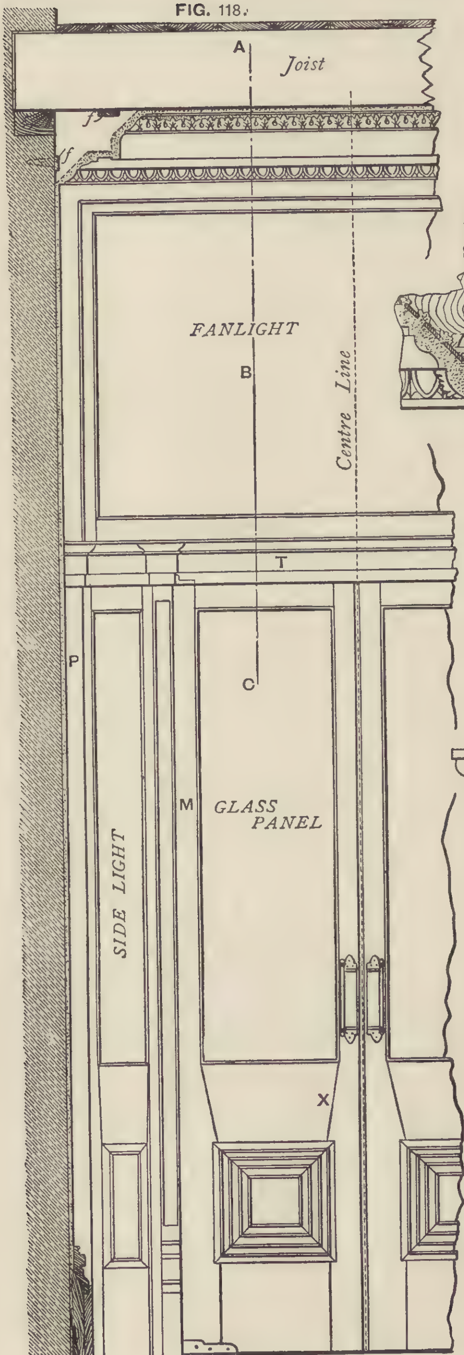
In Fig. 118 the transom T is continuous from wall to wall and tenoned into the side uprights, which rise to the ceiling and are there tenoned into the head. The mullions (M) have stub tenons fitting into mortises on the under side of the transom.

The framework of the side lights is housed into shallow grooves in the side posts or mullions.

The fanlight at the top of the door is kept in position at the sides and top by moulded fillets *ff* screwed to the frame, the bottom rail of the fanlight is connected with the transom by an iron tongue (Fig. 119).

PLATE II.

FIG. 118.



—*ELEVATION*—

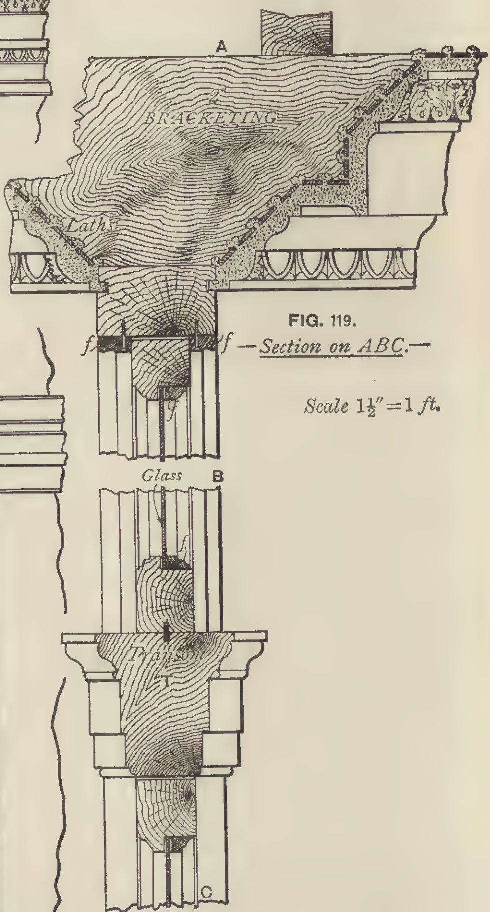
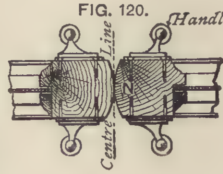


FIG. 119. —*Section on ABC.*—

Scale $1\frac{1}{2}'' = 1$ *ft.*

FIG. 120.



Scale $\frac{1}{2}'' = 1$ *ft.*

Jib Doors are made in appearance exactly like a portion of the wall of the room, the chair rail, dado, etc. (if any) being carried across the door. They were made use of for the sake of uniformity of appearance in a room, to save the expense of having a second door to match one necessarily fixed for use, but are almost obsolete.

Sliding Doors have metal wheels fixed upon either their top or bottom rails: these wheels run upon iron rails fixed above or below the door, which moves laterally.

Fig. 121[1] is the section of a door suspended from hanging rollers, and Fig. 122 of a door running on bottom rollers.

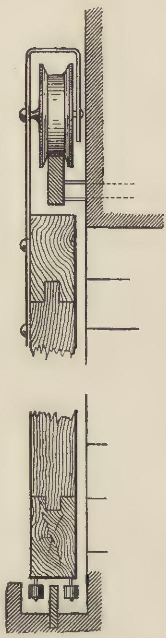


Fig. 121.

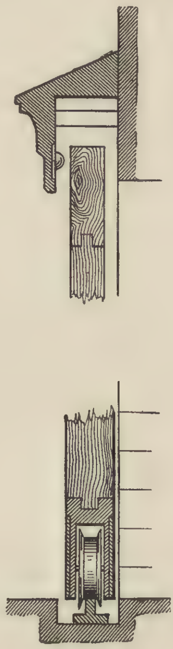


Fig. 122.

Door Frames.—There are several ways of hanging doors, but this course extends only to the consideration of those hung in solid door frames.

Solid Door Frames consist of two posts, whose upper extremities are tenoned into a "*head*" or "*lintel*," and whose feet may be furnished with cast-iron shoes[2] (see Figs. 115, 123), each having a projecting stud in the bottom which fits into a *sill* of hard wood

[1] From the catalogue of Messrs. Rownson, Drew, and Co.

[2] A piece of sheet lead and a slate dowel or a round cast-iron dowel are often substituted for the cast-iron shoe.

or stone. It is better that the frame should in external doors rest upon a stone step, as in Fig. 115, for wood sills soon decay.

The frame is either built in as the masonry progresses, or recesses are left, into which it is afterwards fitted. In the former case the ends of the head are allowed to project beyond the width of the door and posts, forming "*horns*" (H H, Fig. 123), which serve to keep the frame steady in the masonry. Unless the horns are very long, the mortises are sometimes cut through to their extremities, as shown in Fig. 123.

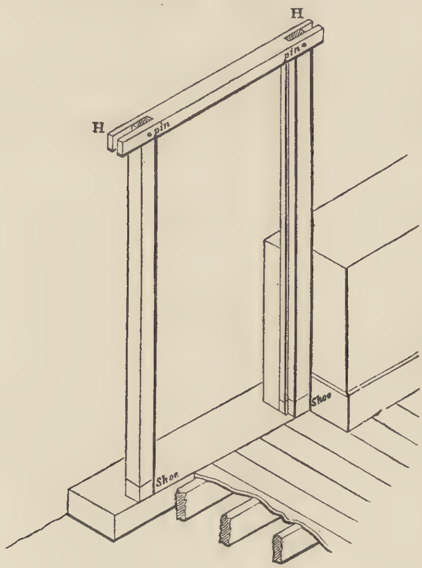


Fig. 123.

These *horns* built into the masonry are liable to rot, and may with advantage be cut off and the joint formed with an ordinary mortise and tenon joint, wedged.

The head of the frame must be fixed by being nailed to wood plugs in the wall or by being wedged into a chase in the wall.

The posts and head for ordinary door frames will fit conveniently into brickwork if they are made $4\frac{1}{2}$ inches square. They are, however, frequently made of much lighter scantling, in which case the recesses to receive them should be diminished accordingly, or spaces will be left behind the frame which are seldom solidly filled in.

The scantlings of solid door frames should vary according to the *width* of the door they have to carry; as they are supported throughout they are not affected by the height of the door.[1]

Width of opening.					Scantling.
ft.	in.		ft.	in.	in. in.
2	3	to	3	0	4 × 3
3	0	to	5	4	5 × 4
5	4	to	7	0	6 × 5

A rebate is formed round the inside of the posts and head, into which the door fits when shut. This rebate is worked through the whole length of the head to the extremities of the horns, the tops of the posts being fitted accordingly.

The inside edge of the rebate on the frame is generally beaded or chamfered, so as to give a finish to the joint between the door and the frame. This bead is not shown in Fig. 123 (see Fig. 114).

Any rebate, chamfer, or bead on the posts should be continued upon the cast-iron shoes where these occur.

The solid frame is generally used for external doors, and its position in the wall is varied according to circumstances.

The frame itself is secured to the masonry either by being nailed to wood plugs, as in Fig. 87, to wood bricks, as in Fig. 89, or by being fastened to forked wrought-iron holdfasts built in, as in Fig. 92, and secured to the frame by a bolt and nut, as in Fig. 125.

In some cases the frame is simply attached to the inside of the jambs of the opening without any reveal, as in Fig. 87; but in order to make a firm job, sinkings or recesses to receive the frame should always be formed in the wall.

When the door is required to open outwards and fold back against the wall, the frame is inserted in recesses formed in the exterior angles of the opening, so that the front face of the frame is flush with that of the wall. An example of this is shown in Fig. 92.

External entrance doors of houses are, however, usually made to open inwards, the frame being fixed in a recess formed on the inside of the wall, as shown in Fig. 124, so that the masonry of the reveal prevents the wind and rain from penetrating between the frame and the wall.

The reveal shown for the external door in Fig. 114 is only $4\frac{1}{2}$ inches thick, but unless there is a porch or other protection in front of the door it is an advantage to leave as great a thickness as possible of masonry in front of the frame, in order that the door may be protected from the weather.

[1] *S.M.E. Course.*

Internal doorways in ordinary houses generally have their jambs covered or lined with wood (see Fig. 114); but in very common

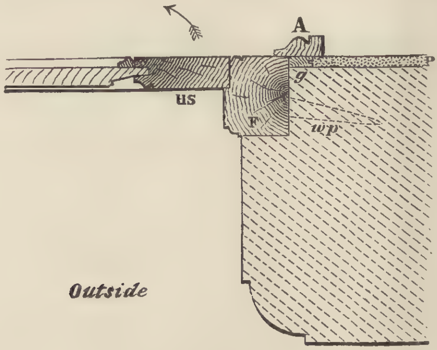


Fig. 124. *External Doorway.*

buildings the linings are omitted. Moreover, in superior buildings of considerable size and massive construction, the jambs are frequently left with the masonry or brickwork showing.

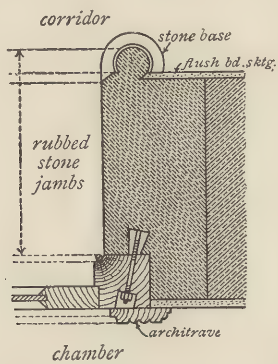


Fig. 125. *Internal Doorway (without Jamb Linings).*

Fig. 125 illustrates such a case. It is taken from the New Law Courts.

WINDOWS.

General Remarks.—Windows may be merely openings in walls, generally that, or they may be projected from the general surface of the wall as *bay windows, oriel windows*, etc.

We have, however, in this course to deal only with the construction of the sashes and frames, and these should always, if possible, be flat, in order to avoid the expense of forms curved in plan, curved glass, etc.

Sizes.—The sizes of windows are regulated both by their external appearance and by the arrangements required for light and ventilation in the rooms.

Several rules are given by different writers for the sizes as regards external appearance. These need not here be entered upon. The undermentioned may be useful to regulate the size as regards internal arrangement.[1]

The area of light should $= \sqrt{}$ cubic contents of room.—*Morris.*

The breadth of window $= \frac{1}{8}$ (width of room + height of room).—*Chambers.*

The height generally from 2 to $2\frac{1}{2}$ times the breadth.

There should be 1 foot superficial of window space to every 100 or 125 cubic feet of contents of the room in dwelling-houses, or 1 foot superficial to 50 or 55 cubic feet in hospitals.—*Galton.*

The window sill should generally be about 2 feet 6 inches from the floor inside.

Windows should (as nearly as the construction will admit) reach to the ceiling, for the sake of ventilation.

Sashes and Frames.—Windows consist of two parts—(1) *The sash* or sashes (including the bars) which hold the glass; (2) *The frame* carrying the sashes.

The sashes may be fixed, arranged in several different ways (see p. 98).

The frames may be solid or hollow. The latter (which are called "*boxed or cased frames*") are required to receive the counterweights when the sashes are hung over pulleys.

N.B.—In the figures illustrating this section the parts are marked with the distinctive letters mentioned below:—

A	Architrave.	*psl*	Parting slip.
B	Bracket.	*s*	Styles.
b	Batten.	*SS*	Stone sill.
bl	Back lining of sash frame.	*SL*	Stone lintel, or window head.
br	Bottom rail of sash.	*SF*	Solid frame.
c	Capping.	*sb*	Sash bar.
f	Fillet.	*sl*	Sash line.
g	Ground.	*sk*	Skirting.
H	Head of sash frame.	*t*	Throat.
h	Hinges.	*tl*	Top lining.
ib	Inside bead.	*tr*	Top rail of sash.
il	Inside lining of sash frame.	*w*	Weights.
l	Laths.	*WB*	Wood brick.
mr	Meeting rails.	*wb*	Water bar.
ol	Outside lining of sash frame.	*wp*	Wood plug.
os	Oak sill.	*WL*	Wood lintel.
P	Plastering.	*WiBd*	Window board.
Pp	Pocket piece.	*x*	Wedge.
p	Pulley.	*y*	Do.
pb	Parting bead.	*Y*	Rough axed arch or concrete lintel.
ps	Pulley style.		

[1] From *Notes on Practice of Building*, printed at Chatham.

SASHES.

The different ways in which window sashes may be arranged are as follows.

Methods of Arranging Sashes.

(*a*) *Fixed*, so that they cannot be opened, see Figs. 133 to 135.

(*b*) *Hinged on either side*, so as to open like a door in one leaf or two, see Figs. 142 to 144.

(*c*) *Hinged on either the top or bottom rail.*

(*d*) *Suspended by lines* over pulleys with counterweights, so that they slide up and down, see Figs. 136 to 141.

(*e*) *Sliding laterally* in a vertical plane, or sliding backwards and forwards in a horizontal or almost horizontal plane.

(*f*) *Hung on pivots* near their centres, see Fig. 132.

The construction of sashes will first be explained, then that of the frames in which they are hung, and then the method of hanging.

Construction of Sash.—The sash itself is of nearly the same construction in all these cases.

FIXED SASHES and HINGED SASHES (see Figs. 135 and 143) consist simply of rails (*r*) and styles (*s*) framed together, and sash bars (*sb*), the spaces thus formed being intended to be fitted in with glass.

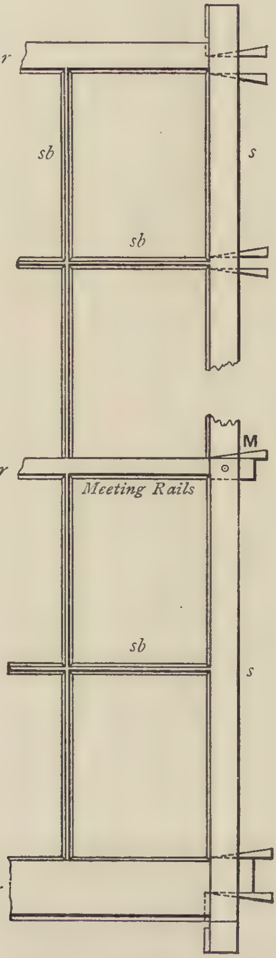
DOUBLE-HUNG or SUSPENDED SASHES.—Fig. 126 shows the construction of an ordinary pair of sashes which are to be hung so as to slide past each other up and down, as described at p. 104, and illustrated in Figs. 136 to 141.

It will be seen that the *rails* (*r*) and *sash bars* (*sb*) are tenoned into the *styles* (*s*) and wedged. In consequence of the narrowness of the *meeting rails* (*mr*), their tenons have to be the full width of the rails, and therefore the mortise has to be cut through to the end of the style, leaving no wood [1] on its outer side, see Fig. 126. The joints between the sash bars are explained at p. 100.

In some cases the lower ends of the styles of the upper sash are continued beyond the meeting rail (*mr*), and furnished with a moulded *horn* (*h*, Fig. 127). This strengthens the joint by providing an outer side to the mortise and prevents the meeting rail from striking the sill when the sash is lowered.

[1] A temporary horn is left on which the sash is wedged up, one wedge being used as at M, Fig. 126.

Sash Bars.—In a fixed sash the vertical sash bars are tenoned into the top and bottom rails, and run continuously between



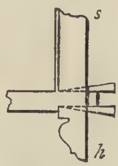


Fig. 127.

Fig. 126. *Sashes to be double hung.*

them, being mortised to receive the horizontal bars, which are cut into lengths and tenoned in between them.

When a sash is to be hung, those bars that are in the direction of the blows or jars it will receive when it is opened or closed, should be made continuous, and the other bars cut and tenoned. Thus, in a sash to slide up and down, the vertical bars, and in a casement the horizontal bars, are continuous.

Fig. 128 is a plan of the junction of a vertical and a horizontal

sash bar for a sliding sash known as *franking*. The vertical bar, (V V) is not severed, but merely mortised to receive the tenons (*t t*) formed on the ends of the portions of the horizontal bars (H H). These latter are *scribed*, as shown from *a* to *b*, to fit the moulding

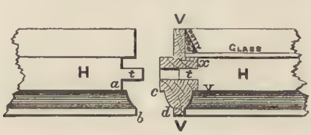


Fig. 128.

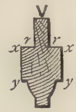


Fig. 129.

(*c d*) of the vertical bar. The tenons are sometimes made the full width of the square (*x y*) of the sash bar, as shown in Fig. 130. When the mouldings of the sash bar form an angular edge as in the lamb's tongue moulds, or frequently in superior work, the joint is *mitred* instead of being scribed—that is, an angular notch is cut upon the vertical bar, and a corresponding angle formed upon the end of the horizontal bar to fit it, as shown in Fig. 130.[1]

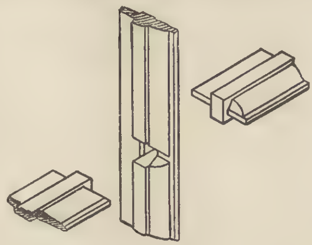


Fig. 130.

In very good work the joint is further secured by a dowel inserted between the horizontal bars to assist the tenons.

The sash bars have a double rebate (*r r*), Fig. 129, on the outside to receive the glass, and a similar rebate is formed all round the outside of those edges of the styles and rails which are next to the glass. In Fig. 128, the glass, together with the putty which secures it, is shown on the right side of the sash bar.

Scantlings of Sashes.

Sashes are generally from $1\frac{1}{2}$ to 2 inches thick. The *rebates* have a depth from the face equal to about $\frac{1}{3}$ the thickness of the sash for ordinary glass, but greater when plate glass and fillets are used (Fig. 119). The width of the *rebates* is about $\frac{1}{4}$ inch.

The lower rail of the upper sash and the upper rail of the lower sash (*mr mr*) are called the "*meeting rails*." They are made wider than the others (each by the thickness of the parting bead), and are bevelled off, as shown in Fig. 137 (or, in some cases, rebated), so as to fit closely where they meet.

The *styles and top rails* are generally about 2 inches wide, and

[1] From *S.M.E. Course.*

the *meeting rails* (in order to obstruct the light as little as possible) about $1\frac{1}{4}$ inch. The *bottom rail* for extra strength is made deeper, generally 3 to 4 inches, and has its under side bevelled (Fig. 137), and sometimes also throated or checked (Fig. 131), to fit the *oak sill.*

The lower surface of the bottom rail should in the best work be checked out to fit the oak sill (see Fig. 131), and its back edge slightly splayed, so as not to strike the inside bead as the sash is lowered. The outer side of the inside bead may also be splayed to fit the lower side, so that the joint between them is tightened as the sash descends.

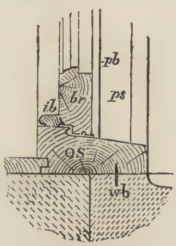


Fig. 131. *Checked Bottom Rail.*

Occasionally the throat is formed nearly on the extreme front edge of the bottom rail, as shown in Fig. 132, so that when closed it is immediately in front of the throat upon the oak sill described at page 103.

When there are two sashes, as in Fig. 137, the under edge of the top or meeting rail of the lower sash is grooved instead of being rebated. A reference to Fig. 137 will show that this is necessary, in order that the meeting rails may be of the same thickness where they come in contact.

The inside of the sash bars, styles, and rails may be left square, moulded, bevelled, or chamfered, according to taste.

An example of a bevelled or chamfered bar is given in Fig. 135, and a moulded bar is shown in Figs. 128 and 136. A square bar is rectangular in section, not ornamented in any way.

Fixed Sashes are put into solid frames, close up against the rebate, and screwed there. A bead stop is sometimes fixed on the outside to keep the joint between frame and sash more secure.

Fanlights are sashes, generally fixed over a door, as shown in Figs. 115, 116. The sash is necessarily on the same side of the frame as the door, in order to be in the same plane with the latter.

Sashes hung on Centres.—These are hung "single" in solid frames (see Fig. 132).

The sash has pivots fixed on the styles in prolongation of its horizontal axis. These pivots fall into slots in small iron sockets fixed in the frame to receive them.

If it is required that the window should fall to and close itself, the pivots are placed slightly above the centre line.

When the window is opened the lower part should move outwards, as shown in Fig. 132.

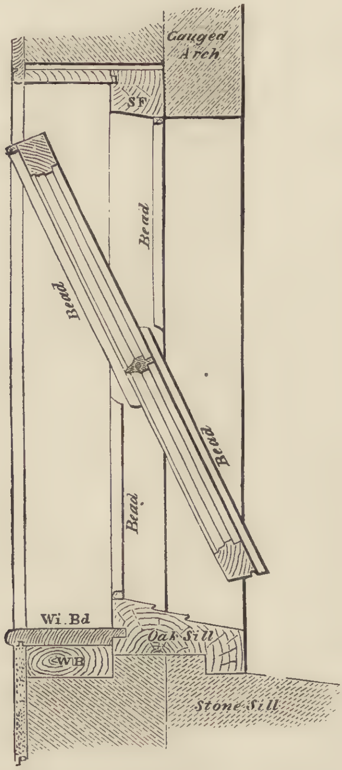


Fig. 132. *Sash hung on Centres.*

In this sash the horizontal bars (if any) extend continuously across, being mortised to receive the vertical bars. In large sashes a centre rail may be introduced.

This window is made water-tight by the following arrangement :—

A bead is fixed on the upper half of the outside, and on the lower half of the inside of the frame against which the sash abuts ; the remaining portion of the bead is fixed upon the sash itself, so as to show a continuous bead when the window is shut.

Instead of fixing separate beads upon the frame, it is sometimes rebated to answer the same purpose.

Sashes hung in this manner are well adapted for windows out of reach, as they can be opened and shut from below by cords.

Sashes sliding laterally are seldom required. Those which move in a vertical plane may be arranged to move on rollers between beads on a solid frame, or the under side of the sash may be deeply grooved so as to fit over a water bar fixed in the sill.

Sashes sliding in a horizontal or nearly horizontal plane may also run on small rollers. An example of them is given in Chapter VI. in connection with skylights.

WINDOW FRAMES.

It has already been mentioned that window frames are of two kinds, *i.e. solid* and *hollow,* the latter being known also as *boxed* or *cased.* These will now be described in turn.

The Solid Window Frame is very simple, consisting, like that of a door, of a head, two posts, and a sill.

A rebate is run all round the frame to receive the sash, as it shuts against it, or a stop may be nailed on to fulfil the same object.

If the sash is to be fixed, the rebate should be on the outside of the frame, as in Fig. 134, for then the pressure of the wind tends to tighten the joint between them; but if the sash is to be movable, the rebate may be either outside, as in Fig. 134, or inside, according to the way the sash is hung.

It is a very common practice to fix solid frames with the rebate inside, as it is often convenient for the sash to open inwards; but it is an advantage to have the rebate outside if possible, for in that case any water which finds its way in between the sides of the frame and the sash is stopped by the projection of the rebate, against which the sash shuts, whereas when the rebate is inside, any water penetrating at the sides is conducted downwards until it reaches the sill and trickles over it into the room.

The sill[1] (*os,* Fig. 134) is generally made of hard wood, such as oak or pitch pine, as it is much exposed; its upper surface is bevelled to fit the lower rail of the sash, "weathered" to throw off the water, and frequently throated, as in Fig. 137, to prevent the water from being blown along it; occasionally it is double throated, as in Fig. 132.

In order to prevent the wet from working in underneath the oak sill, a metal tongue or "water bar" (*wb*) is inserted between it and the stone sill, as shown in Fig. 134, or a step is made in the upper surface of the latter, as in Fig. 132. This last arrangement is unusual and expensive.

Figs. 133, 134 show the external elevation and cross section of a small fixed sash in a solid frame. The plan below (Fig. 135) is on double the scale of the other figures.

"Boxed" or "Cased" Frames.—In these the styles or side-

[1] Sc. sometimes called *Sole.*

posts of the frames are hollow boxes or "cases," so made in order to receive the weights which counterbalance the sashes.

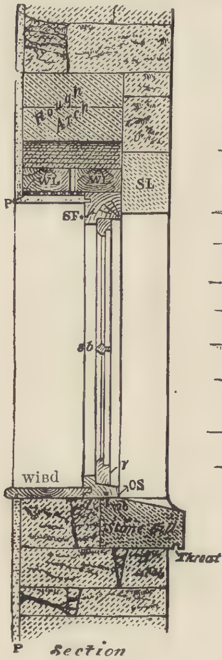


Fig. 134.

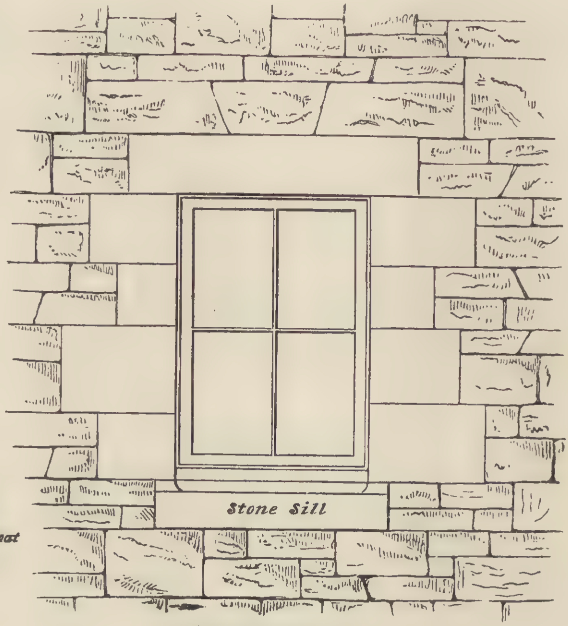


Fig. 133.

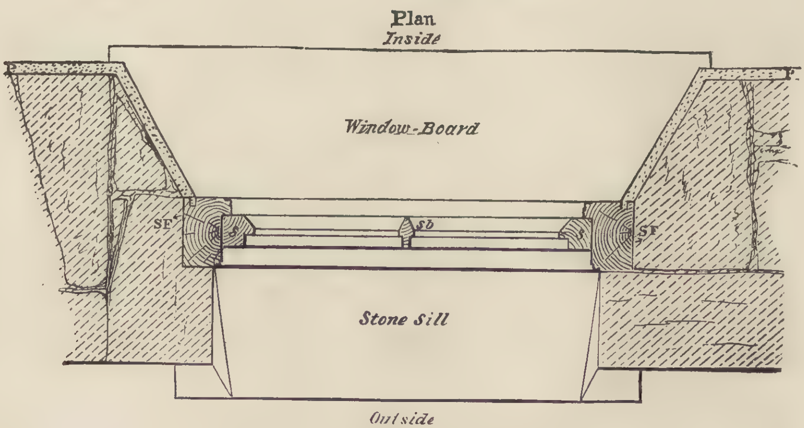


Fig. 135. *Fixed Sash in Solid Frame.*

CASED FRAMES WITH DOUBLE-HUNG SASHES IN A THICK WALL. —Fig. 136 is the plan and Fig. 137 the vertical section of a window with boxed frame and sliding sashes, double hung.

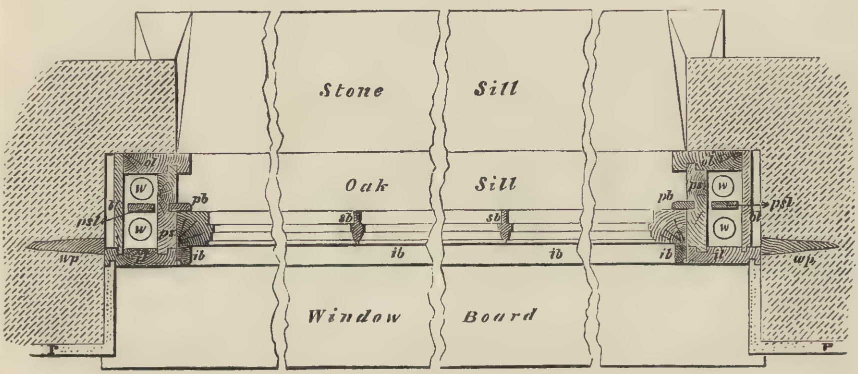
Fig. 138 is an interior elevation of part of the sash and frame, with the inside lining removed, so as to show the interior of the case.

These figures are necessarily broken into portions for want of space.

The exterior elevation of this window is shown in Fig. 139, and the interior elevation in Fig. 140. Both of these figures are on a reduced scale.

Each box or case consists of the *back lining*[1] (*bl*), the *inside lining* (*il*), and the *outside lining* (*ol*), the side nearest the sash (*ps*) being called the "*pulley style*," because it carries the pulleys over which run the sash lines supporting the weights.

These portions of the casing should be grooved and tongued together, as shown in Fig. 136, but in common work the grooves and tongues are often omitted.



Plan (*Scale* 1″ = 1 *ft.*

Fig. 136.

The upper end of the pulley style is dovetailed (or, more often, grooved) into the *head* of the sash frame (H), and the lower end is housed into the sill, and there secured by a horizontal wedge (*x*, see Fig. 138).

Down the centre of the pulley styles is formed a groove, into which fits a narrow strip (*pb*), called the "*parting bead*," because it separates one sash from the other.[2]

[1] Sc. *Back boxing.*

[2] The parting bead is sometimes carried round the upper part of the frame, being attached to the under side of the head, as in Fig. 141. This is an advantage, as it helps to keep the sash steady, and to tighten the joint.

Scale 1″ = 1 ft.

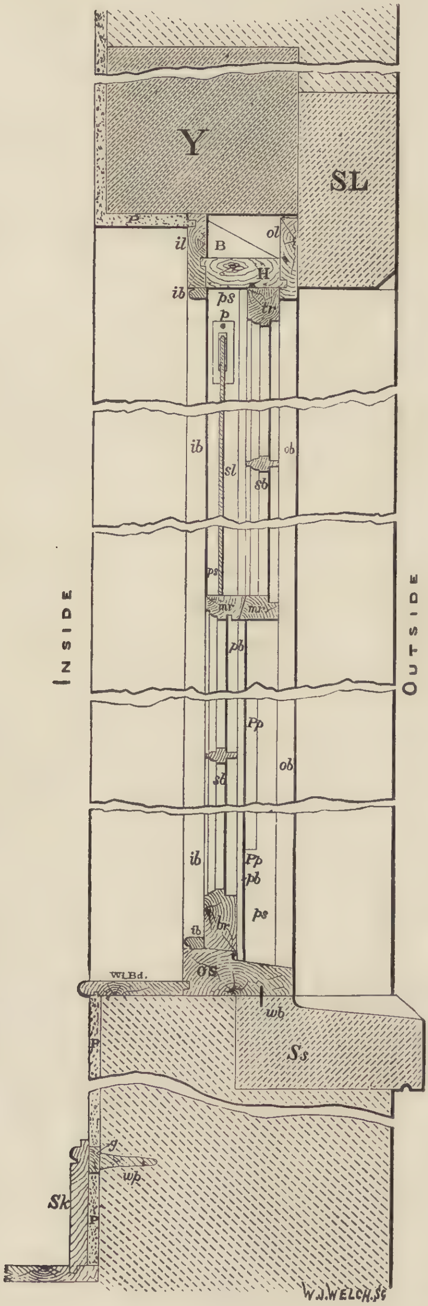
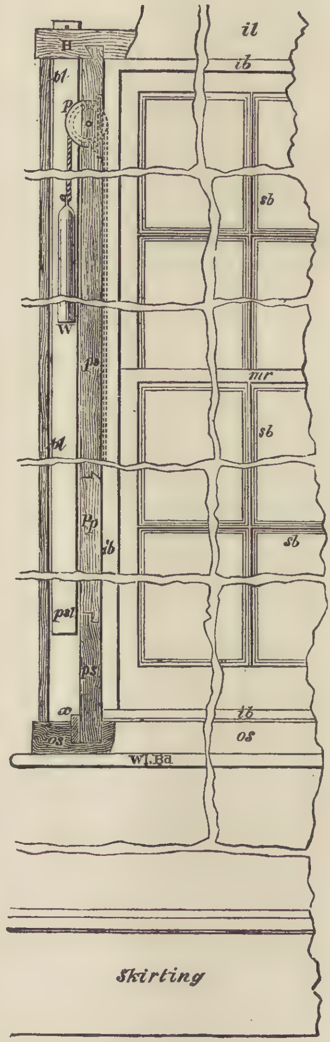


Fig. 137.



Elevation of part of Interior
(the inside lining having been removed)

Fig. 138.

The parting bead is not fixed, as the outer sash cannot be put in without removing it temporarily.

The inside bead should be fixed with screws, so that it also can easily be removed if required to put in or take out the sashes.

The inside bead (*ib*) is made deeper than the thickness of the inside lining (*il*), so as to cover the joint between the inside lining and the pulley style (*ps*, see Fig. 136).

The projecting end of the outside lining (*ol*) is sometimes rounded, as shown in Fig. 141.

It will be understood that there are two sashes—an upper and a lower. The upper sash slides in the outer half of the frame, between the parting bead (*pb*) and the end of the outside lining (*ol*) ; the lower sash slides in the inner half of the frame, between the parting bead (*pb*) and the inside bead (*ib*).

The *sill* is similar to that already described at p. 103. A notch is formed in its upper surface to receive the lower end of the parting bead. The penetration of water between it and the stone sill upon which it rests is prevented by a metal water bar, as previously described.

The upper parts of the styles of the sashes have grooves taken out of their sides about $\frac{1}{2}$ inch square, and extending downwards about 6 inches from the top, to receive the ends of flax ropes or "*sash lines*" (about $\frac{3}{8}$ inch in diameter) ; these pass over iron or brass pulleys (*pp*, Figs. 137, 138) fixed in slots near the top of the pulley styles, and are attached to the weights (*ww*) which counterbalance the sashes.

The direction of the sash line in Fig. 138 is shown by the dotted line. The lower end of the line, after passing through the groove in the sash style above mentioned, enters a hole bored obliquely inwards for 3 or 4 inches in depth, until it meets a larger hole sunk in the side of the style, in which it is secured by a knot which is nailed to the style. This knot is not shown in Fig. 138, as it would occur just where the figure is broken.

The weights are of common cast iron, 14 to 24 inches long, and either circular or rectangular in section. The weights should be together slightly lighter than the sash, and they hang in the boxes, being separated (to prevent them fouling) by the *parting slip* [1] (*psl*), which may be either of wood or zinc.

The upper end of the parting slip is passed through the head

[1] Sometimes called *Pendulum Slip*.

of the frame and suspended by a nail driven through it, as shown in Fig. 138.

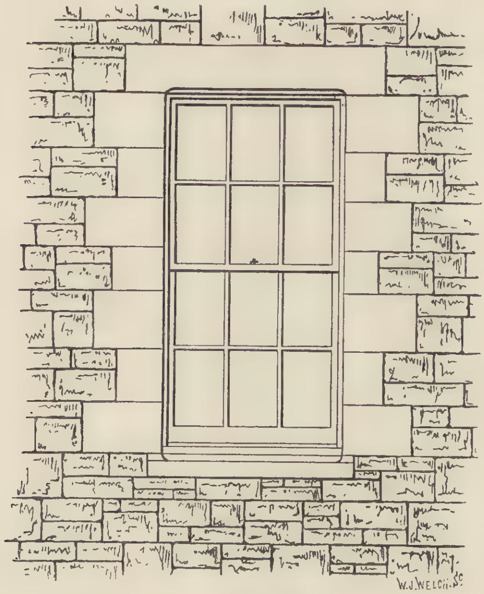


Fig. 139.

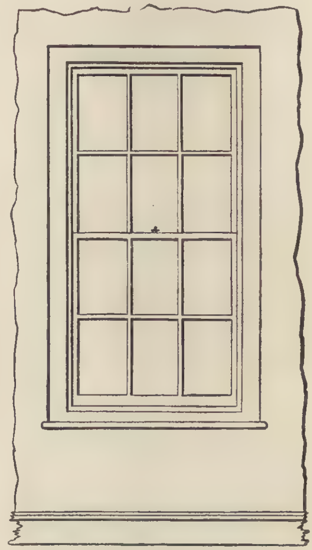


Fig. 140.

Nearly at the foot of each pulley style a rectangular hole is cut to admit the weights, which can thus be got at whenever necessary.

This hole is called the "*pocket*," and is covered by a flush lid or "*pocket-piece*,"[1] the lower end of which is rebated, and the upper side both rebated and undercut, so as to fit into the pulley style (see *Pp*, Fig. 138).

The pocket is sometimes placed in the centre, immediately behind the parting bead, as in Fig. 137, but it is more convenient and easier to open if placed in the pulley style, forming the face of the inner box, so that it is just behind the lower sash when closed.

To open the window the lower sash is thrown up or the upper one pulled down, or both. When the window is closed, the sashes are secured in position by a small clip or sash fastening fixed on the meeting rails.

In the example shown in Fig. 137, the inside lining above the head is stiffened by a bracket, B; very often a small block is placed

[1] Ir. *Foxing*.

in each of the lower corners for the same purpose, as in Fig. 141.

As the description of linings is given in the following chapter, pages 129 to 134, the case selected for illustration in Figs. 136, 137 is one of a window in a thick wall of a somewhat inferior building. The jambs inside the window are merely plastered, whereas in a superior building they would be lined, as described in Chapter VI.

The ledge formed by the thickness of the wall within the sill is, however, protected by a window board (*Wi Bd*) tongued into the back of the sill, and grooved to receive the edge of the plastering.

The inside lining is also grooved for a similar purpose.

Cased Frame with Double-hung Sashes in a Thin Wall.—Even in superior buildings windows may necessarily be fixed without linings. This occurs when the wall is thin, affording barely space for the boxed frame, together with a sufficient thickness of brickwork for the reveal.

Fig. 141 is a section of the upper portion of a window, in 9-inch brick wall.

The joint between the inside lining and the plaster is covered by an architrave (A), the description of which does not fall within the limits of this chapter, but will be found on page 125.

The frame is secured in position at the sides by being nailed obliquely through the inside lining to wood bricks built into the reveal, and at the head by being nailed through the inside lining to the wood lintel.

In this case the head is furnished with a top lining (*tl*); the inside lining is secured to this and to the lintel, and a bracket similar to that in Fig. 137 is therefore unnecessary.

It will be seen that Figs. 137 and 141 give illustrations of the different methods in which the weight of the back of the wall above the opening is supported. In Fig. 141 there is a wood lintel (WL), relieved by a rough segmental arch of the description shown in Part I. Fig. 99. In Fig. 137 Y is a flat arch for which a concrete beam is sometimes substituted, thus in either case dispensing with the wood lintel, the evils of which have been pointed out in Part I. p. 11.

If the method illustrated in Fig. 141 were applied to the thicker wall shown in Fig. 137, two lintels of wood or breeze would be required to support the back of the wall above the opening. Such a case is shown in Fig. 134. The under sides

of the wood lintels are either hacked or lathed to form a key for the plaster soffit; or in superior work they are covered by a wooden soffit lining, as described on page 129.

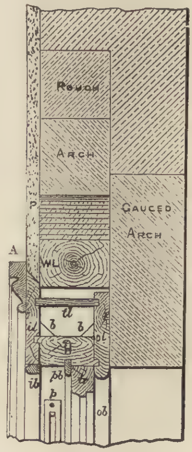


Fig. 141.

Single-hung Sashes.—These are constructed in exactly the same manner as those just described, and so are the frames to contain them; but the upper sash, instead of being suspended, is fixed, and prevented from descending, by stops nailed under its bottom rail, the lower sash only being hung with counterbalance weights, as above described.

In some cases, however, it is more convenient to fix the lower sash, the upper one being hung in the usual manner.

Fixing Cased Frames in Position.—Cased frames are generally secured in position by wedges, or pairs of wedges, driven in at the sides between the back linings of the boxes, or cases, and the masonry; and at the head by wedges between the top of the frame and the soffit of the relieving arch or lintel. (These last-mentioned wedges should be driven in over the pulley styles, so that they may not bear upon the unsupported part of the head of the frame and cause it to bend.) The frame should, however, be made more secure at the sides by being nailed obliquely through the inside linings, and wedges where they occur, to plugs, wood bricks, or breeze fixing blocks inserted at intervals in the masonry or brickwork (see Fig. 136, and Part I.), and at the top by being nailed to plugs inserted in the inner flat arch, or directly to the concrete or wood lintel, according to the construction adopted. When the inside lining is attached to the wood lintel, it should be nailed only near the ends of the lintel where it bears upon the wall, so that the lintel may be free to sag in the centre without bearing on the frame.

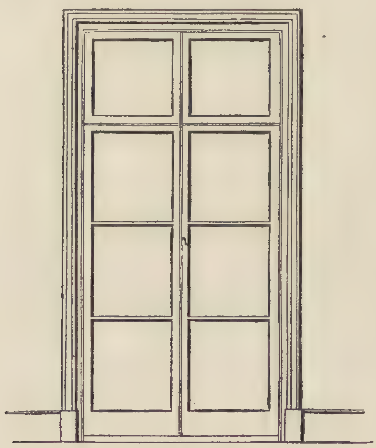

Inside Elevation

Fig. 142.

Cased frames are often built in as the walling progresses, in which case the head should be made longer than the width of the frame, so as to form *horns* somewhat similar to those of the solid door frame shown in Fig. 123, but much sounder work is made if the frames are fixed after the brickwork is complete; screeds can then be run up to which the frame can be accurately fitted.

French or Casement Windows are those in which the sashes are hinged vertically and open like a door.

In exposed places they should be made to open outwards, as then the wind pressing upon them from the outside only makes them close more tightly.

The frames for these windows are solid, having a rebate cut round the outside to receive the sash.

The back of the hanging style of the sash is generally shaped so as to fit into a circular recess formed in the frame, as shown at *x*, Fig. 143, in order to make the joint as tight as possible.

These sashes have continuous horizontal bars, the vertical bars, if any, being framed into them.

It is difficult to keep the wet from entering these windows, especially if the sashes are hung folding in two leaves.

To prevent this various methods have been devised; among the best is the curved groove on one style and corresponding projection on the other fitting into it, as shown in the figure.

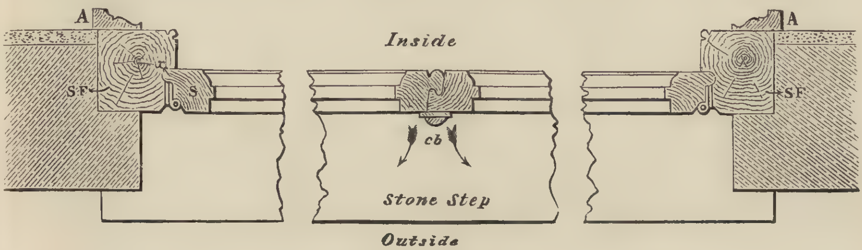


Fig. 143.

The joint is often further protected by a cocked bead (*cb*) planted on the outside.

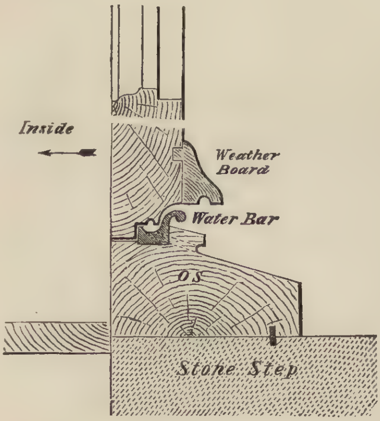


Fig. 144.

The frames of casement windows are often placed so as to be flush with the face of the wall, in order that the sashes may fold back against the wall when open.

When a casement window extends down to the floor it becomes in fact a glass door, and is often made to open inwards; in such a case it is very difficult to keep water from entering between the foot of the door and the sill, which, if rabbeted, is so necessarily

on the inside. To overcome this objection several different plans have been adopted.

One of these is shown in Fig. 144. The rain is prevented as much as possible from beating in at the joint by a moulded and throated weather board, and by a metal water bar fixed in the oak sill. Any wet that may penetrate between these is caught in the groove formed in the sill at the back of the water bar, and conveyed away through a hole bored in the oak sill as dotted.

In this arrangement the water bar is rather in the way of any one entering the door. To avoid this it is often omitted, or "self-acting water bars" are used. These are attached to the lower rail of the sash, move with it, and when it is shut, turn over to secure the joint. Any detailed description of these contrivances would be beyond the range of this work.

In order to get rid of the water penetrating between the frame and the sides of the sash, the rebate in the former is grooved down the centre, and a similar groove is formed down the side of the style of the sash. These two grooves meeting one another form a channel down which the water runs into the groove behind the water bar aboved noticed.

Furniture and Hinges.—The description of the different kinds of furniture and hinges in use does not fall within the scope of this work, but it is required that the student should know the position in which they are fixed.

Position of Furniture.—Doors.—The "furniture" of a door depends upon the situation and nature of the door itself.

There are several kinds of locks and fastenings in use, of which a few only can here be mentioned, and none described. The former are fixed in or upon the lock rail, at a convenient height for the hand. The position for fastenings varies according to their description and the use for which they are intended.

For ledged, framed and braced, or other common doors, the only furniture required is a *Norfolk* or *thumb latch* and a *rim lock.* These are placed as shown on Figs. 86, 90, 91.

For superior doors, such as those in the principal rooms of good houses, mortise locks, concealed in the thickness of the door, with spring bolts and ornamental knobs, are chiefly used, and also finger-plates (*fp*), fixed just above and below the lock on both sides of the door (see Fig. 96). The lower finger-plate is very often made smaller than the other. The small bolt knob shown in this figure has gone out of fashion ; when used its position varies. It is sometimes in a line with the large knob, or slightly above or below it, according to the make of the lock.

The edge of the keyhole is often protected by a brass plate or *escutcheon*

screwed on over it, and having a hole in it a little larger than the keyhole. Dust and dirt are excluded by the use of a small hanging cover (see Fig. 96) pivoted above the keyhole.

For common or external doors heavier locks are required. These are generally iron-cased *rim locks* (see Figs. 93, 116), or for some doors wooden *stock locks* of an ornamental exterior are used.

External doors require to be further secured by *barrel* bolts, either horizontal, or (when hung folding) by vertical bolts at the top and bottom, sliding into the head and sill respectively (see Fig. 116.

Chain and barrel fastenings are also required on the inside of outer doors, in order that they may be secured when partially open. The plate at one end of the chain is screwed to the door frame, while a knob at the other end slides in a hollow barrel fixed to the door.

Position of Hinges.—This is shown for the *cross garnet hinges*[1] on the ledged doors in Figs. 86, 88, also for the *hook and strap hinges* in Fig. 90, and for the *butt hinges*[2] in Figs. 93, 96, 116.

In framed doors the upper hinge is fixed on the edge of the style just below the level of the lower edge of the top rail, in order to be clear of the tenon of the rail; for the same reason the lowest hinge is placed just above the level of the bottom rail. When there are three hinges, the intermediate one is placed halfway between the others.

The knuckle of the hinge may be placed so as to coincide with the bead on the door-frame, as in Fig. 116. This is often done in good work to preserve the appearance of the bead intact, but a very general practice is to let half the knuckle into the door, as in Fig. 96, the remaining half being let into the frame.

To enter upon the different methods of fixing hinges would require long descriptions and diagrams; the subject is a somewhat intricate one, and does not form a part of this volume.

Windows.—The different fastenings in use for sashes, shutters, etc., are so numerous that it will be impossible to do more than notice one or two that are absolutely necessary.

Sliding sashes require a spring clip or *sash-fastener* to keep the meeting rails in their proper position when the window is closed; in some cases this is done by driving a *thumbscrew* through the meeting rails.

The lower sash, if heavy, should be provided with small brass handles or *lifts* screwed to the lower rail.

Casement windows require fastenings to secure the sashes when shut, and also to hold them back when open. The latter are fixed in the face of the wall when the sashes fold back upon it, but if they only open at right angles the fastenings are on the sill.

A common form in this latter case is a flat iron bar pivoted to the sash, with holes throughout its length which fit upon a pin fixed on the sill. The position of the hole selected regulates the degree to which the sash is opened.

When hung folding, a vertical *flush bolt* is required at the top and another at the foot of the style of the sash first closed.

Sometimes there are top and bottom bolts connected by a rod, so arranged that the turn of a handle in the centre shuts both bolts, and also

---

[1] Sc. *Cross-tailed hinges.*

[2] Sc. *Edge hinges.*

secures the sashes to one another. This is known as the "*Espagnolette bolt.*"

Sashes hung on centres, when out of reach, have a cord attached to the top and bottom rails, and secured to a belaying pin below ; or, if they can be easily got at, they may be secured either when open or shut by the quadrant fastening above described.

CHAPTER VI.

JOINERY—(*Continued*).

MOULDINGS.

MOULDINGS are required merely for ornament. The most ordinary forms are generally parts of a circle in section; and it is recommended that they should not have much projection, the lines of shade being produced rather by deep grooves.

When a moulding is formed on the edge of a piece of timber in the substance of the wood itself, it is said to be "*stuck*," see Fig. 145.

When it is on a separate slip of wood, and attached to the piece it is to ornament, it is said to be "*laid in*," or "*planted*," see Fig. 160.

These terms are the same as those used for beads and explained in Chapter V.

In ordinary panelled work the mouldings are as a rule in separate slips, bradded or "planted" on to the inner edges of the frames, not on to the panels, as the shrinkage of the latter would draw them away from the frame.

If, however, the moulding is "stuck" on the frame, the groove for the panel should be deeper than the moulding, otherwise, when the framing shrinks, daylight will be seen through the open mitred corners of the moulding.

Figures 145 to 150 are sections of some of the commonest classical mouldings, which are named as follows:—

Fig. 145.

The Torus (Fig. 145) is a semi-cylindrical projection, surmounted by a flat band called a "fillet."

The Double Torus consists of two such semi-cylindrical projections, the upper one being smaller than the other and surmounted by a fillet.

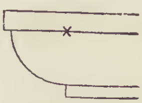


Fig. 146.

The Ovolo (Fig. 146) is a curved convex projection surmounted by a fillet.

The ovolo shown in Fig. 146 is a quarter-circle in section, but it may be a portion of an ellipse or hyperbola.

The Double Ovolo consists of two ovolo mouldings opposite to one another, as in the sash bar Fig. 128.

The Cavetto (Fig. 147) is the reverse of the Ovolo, being a concave quadrant.

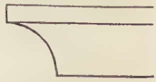


Fig. 147.

The Ogee or Cyma Recta (Fig. 148) consists of two curves tangent to one another, the upper being concave and the lower convex.

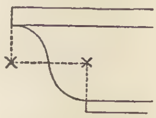


Fig. 148.

The Reverse Ogee or Cyma Reversa (Fig. 149) is composed of the same parts as the Ogee, but reversed, the convexity being in this case uppermost.

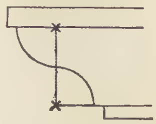


Fig. 149.

The curves composing the two last-mentioned mouldings may be either quadrants, as in the figures struck from the centres marked, or the moulding may be varied according to taste, by using flatter curves.

The Scotia is a moulding chiefly used for bases and constructed thus :—

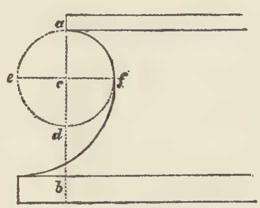
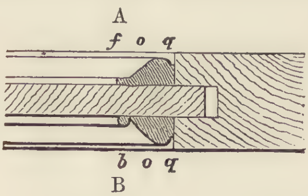


Fig. 150.

In Fig. 150 trisect *a b* in *c* and *d;* from centre *c*, with radius *c a*, describe the circle, *a e d*, a quarter of which forms the upper part of the moulding ; draw *c e* at right angles to *a b*, cutting the circle in *e;* from centre, *e*, with radius, *e f*, describe the curve, *f b*, forming the lower portion of the moulding.

When mouldings are formed by a combination of parts of well-known form, they are distinguished by names expressing the combination of those parts.

Thus the moulding at A in Fig. 151 is known as "*Quirk Ovolo and Fillet,*" being made up of these three parts, *q o f.*



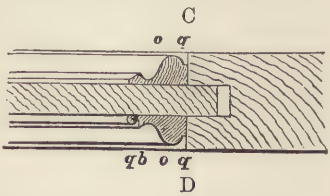


Fig. 151. Scale, 2 inches = 1 foot. Fig. 152.

The moulding at B in Fig. 151 is a "*Quirk Ovolo and Bead.*"

In Fig. 152 the moulding at C is a "*Quirk Ogee*"*;* that at D is a "*Quirk Ogee and Quirked Bead.*"

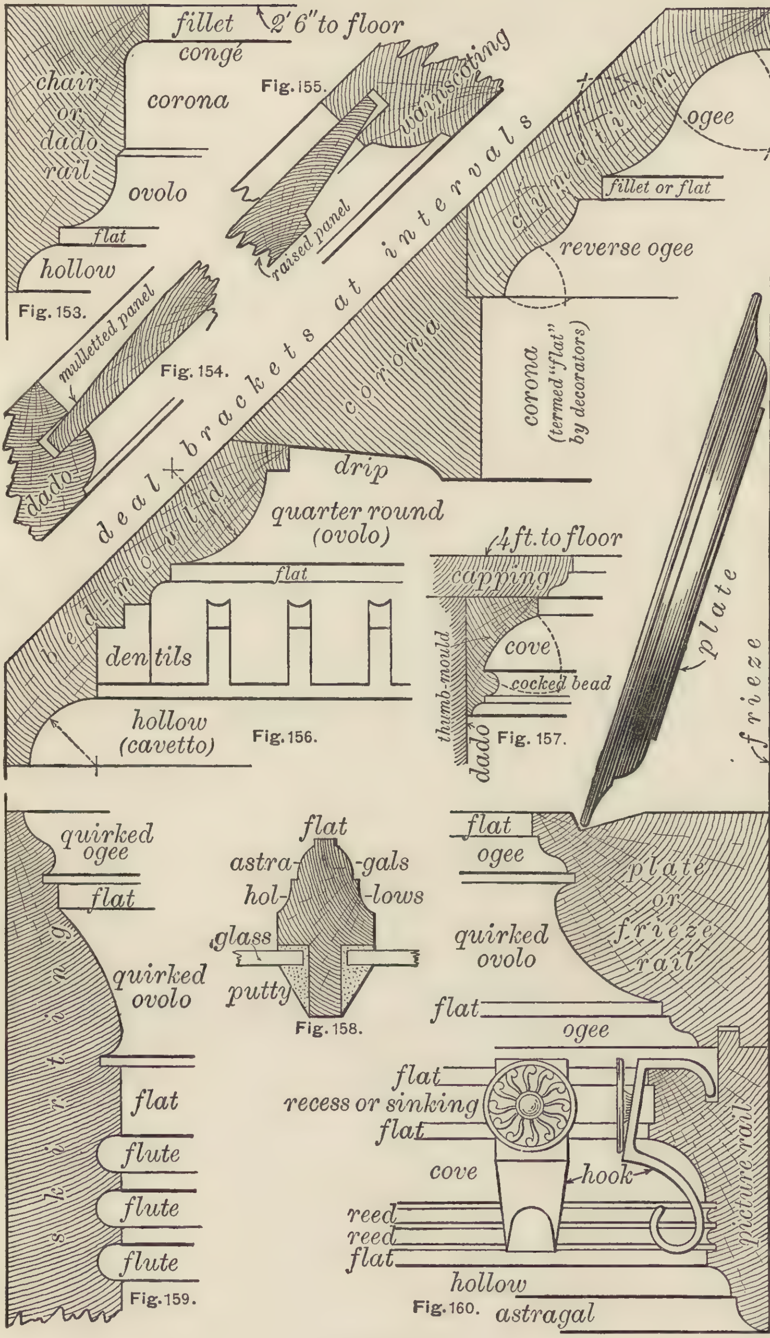

fillet
2′ 6″ to floor
congé
chair or dado rail
corona
ovolo
flat
hollow
Fig. 153.
Fig. 155.
wainscoting
raised panel
mulletted panel
Fig. 154.
dado
deal brackets at intervals
cymatium
ogee
fillet or flat
reverse ogee
corona
corona (termed "flat" by decorators)
drip
bed-mould
quarter round (ovolo)
flat
den tils
hollow (cavetto)
Fig. 156.
4 ft. to floor
capping
thumb-mould
cove
cocked bead
dado
Fig. 157.
plate
frieze
quirked ogee
flat
quirked ovolo
flat
flute
flute
flute
skirting
Fig. 159.
flat
astra- -gals
hol- -lows
glass
putty
Fig. 158.
flat
ogee
quirked ovolo
plate or frieze rail
flat
ogee
flat
recess or sinking
flat
cove
hook
reed
reed
flat
hollow
astragal
picture rail
Fig. 160.

PLATE III.

The above are only a few of the commonest classical mouldings, besides which there is an infinite variety belonging to Gothic and other styles of architecture, and new ones are constantly being designed. At one time they were all formed by hand; and it was therefore important to know how to construct the various forms, but they are now nearly always made by machinery.

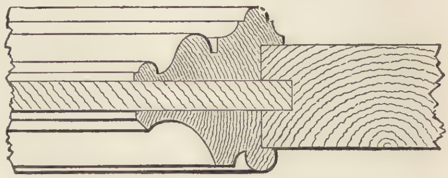


Fig. 161. Scale, 2 inches = 1 foot.

Bolection Mouldings are those which project beyond the face of the framing, as in Fig. 161.

They are used in order to give a massive appearance and heavy decoration without increasing the thickness of the framing.

Plate III. illustrates on a scale of half full size the application of mouldings to various constructions in joinery. Figs. 153 to 157 are from an eighteenth century building, and Figs. 158 to 160 modified from the moulding books of Messrs. Elliott of Newbury.

JOINTS.

In this section it is proposed to describe some common forms of joints, which have been partially referred to in the preceding chapter, and are now treated at greater length.

The "arrises" or corners of all angle joints in good work should be kept as sharp as possible.

Angle Joints.—Mitre Joints.—When the length of the joint is not great the pieces are cut to a bevel, so that the plane of the joint bisects the angle; this is called the "mitre."

This joint depends entirely upon the glue unless it is strengthened by a slip feather, as dotted in Fig. 162.

If the boards are of different thicknesses the joint is made as in Fig. 163.

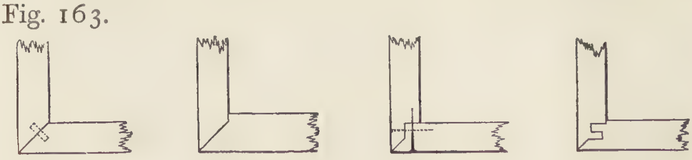


Fig. 162. Fig. 163. Fig. 164. Fig. 165.

Fig. 164 is a modification of the above; it is a good joint for exterior angles, and can be nailed both ways.

This joint is useful for connecting angles such as those of dados or skirtings.

In Fig. 165 the parts are kept together by the form of the joint itself, but it requires a great deal of labour, is very liable to split, and not often used.

Keyed Mitre Joint.—A mitre joint is frequently keyed for strength by inserting thin slips of hard wood covered with glue, as shown in Fig. 166. These may either be horizontal as at K, K, or inclined as at K_1.

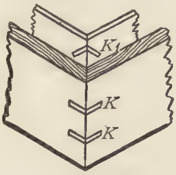


Fig. 166.

A keyed mitre is most generally used for joints visible only on the inside, as the keys are unsightly.

Butt Joints.—In mitre joints the shrinkage of the boards in width, as dotted, does not open the external angle of the joint, though the inner angle does open slightly, as shown by the dotted lines in Fig. 167.

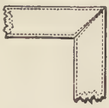


Fig. 167.

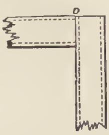


Fig. 168.

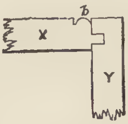


Fig. 169.

Fig. 170.

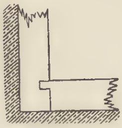


Fig. 171.

When, however, one piece is *butted* against the other, the piece that has its grain parallel to the plane of the joint is drawn away from the other as it contracts, leaving an opening at *o* (Fig. 168).

To hide this opening by its shadow a bead is often "stuck" on to the piece, as shown at *b*, Fig. 169.

Or in angles exposed to injury, such as those of chimney breasts, passages, etc., a bead is formed so as to avoid the sharp arris (Fig. 170).

This forms what is called a *staff bead.*

Interior angles, such as those of dados or skirtings, may be formed with a simple joint as in Fig. 171. In this case the opening caused by shrinkage is not visible (except on the top edge, which is generally mitred as far down as the depth ot the moulding), as it is covered by the wall.

The above joints, slightly modified, are all applicable to acute and obtuse, as well as to right angles.

A common joint for uniting the angles of cisterns or troughs is shown in Fig. 172.

When the angles on both sides are seen, one piece may be housed into the other, as in Fig. 173.

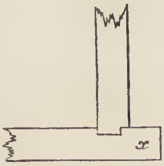


Fig. 172.

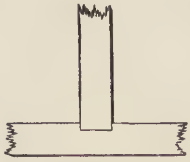
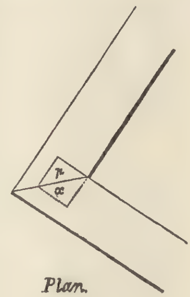


Fig. 173.

If the end, *x*, cannot be left on, the tongue must be made smaller as in Fig. 171, so that sufficient wood may be left on the outside for strength.

DOVETAIL JOINTS.—*The common Dovetail* has already been described in Chapter V.

The Mitred or Secret Dovetail is chiefly used by cabinetmakers for highly-finished drawers and boxes, when for the sake of appearance it is desirable that the dovetails should not be visible. In this joint not much more than half the thickness of the boards is dovetailed, the outer portion (*s t*, Fig. 175) being mitred as shown, so that the dovetails may not show on the sides of the exterior angle.



Plan.
Fig. 174.

In order, further, that the dovetails may not be visible upon the upper surface of the boards to be united, the top of the joint is mitred right through the thickness of the board, *a c*, for a short depth (from *a* to *b*). This may also be done on the lower surface if that is likely to be seen.

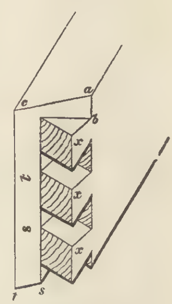


Fig. 175.

Fig. 175 shows only one of the boards to form the angle, but the construction of the other will be readily understood, as it is cut to fit into the projections and indentations of the one shown. The spaces between *x x x* in the figures are the *sockets*, the corresponding projections on the opposite board being called the *pins*

This joint is not so strong as the common dovetail.

The Lap Dovetail is a joint in which the pins on one board, B, do not extend entirely through the thickness of the board A, but are concealed by a portion of the board which is not cut through. In this case, of course, the pins of the board A only are visible.

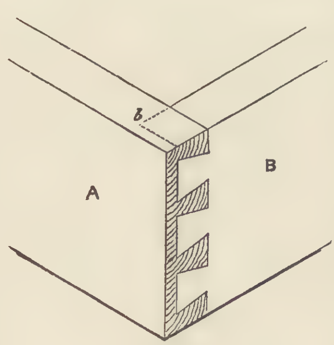


Fig. 176.

This joint is well adapted for the fronts of drawers. The piece, A, which forms the front shows no dovetails, while B forms the side in which their appearance is of no consequence, as it is not seen except when the drawer is open.

KEYS.—When plain surfaces of boarding of considerable extent

are required, as in dados, window backs, wall linings, etc., the boards are generally ploughed and tongued and joined with glue.

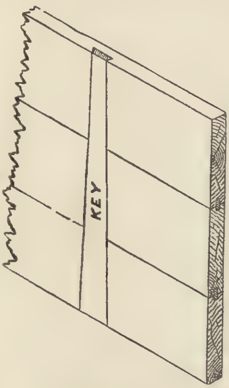


Fig. 177.

Tapering pieces of wood called "keys," very well seasoned, are often let into a wide dovetailed groove across the back, as shown in Fig. 177.

These keys keep the surface of the boards in the same plane, and allow the work to shrink and expand according to the weather.

The edges of boards to be united are sometimes rebated at the back of the joint, and strips of wood are glued in, so as to keep the edges close together. Boards so secured must be very well seasoned, or they will split.

Double Dovetail Keys are small pieces of hard wood, of double dovetail shape, let in, with the grain, across the joint to be secured.

Hammer-headed Key Joint.—When a heavy circular-headed frame consists of several curved pieces, the parts are often kept together by keys of hard wood, of the shape shown at H K in Fig. 178, glued in.

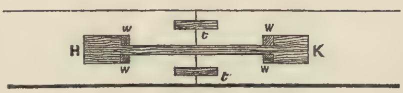


Fig. 178.

If the pieces are very wide, a cross tongue, *t*, is put in on each side of the key, and the joint is tightened up by wedges, *w w*.

Screw bolts may be substituted for the keys, the cross tongue still being used.

Clamping.—Boards are sometimes kept tight together at the ends by a "clamp" (C C, Fig. 179) running across them, grooved

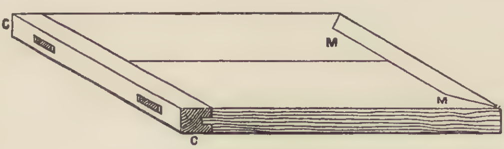


Fig. 179.

on the edge to receive a tongue left on the boards, which are thus free to shrink in width. In the best work tenons are also formed on the ends of the boards, which fit into mortises formed in the clamp.

In some cases the boards are cross-grooved, and the clamp tongued

Mitre Clamping.—When it is advisable, for the sake of appearance, to conceal the ends of the clamp, they are mitred back, as shown at M M, Fig. 179.

Glued Joints.—When it is required to glue large pieces together, the wood should be thoroughly dry, the edges well warmed at a fire, and clean,—the glue as hot as possible.

While the edges are warm they are covered with a coating of glue, and rubbed together, so that the superfluous glue is squeezed out. In intricate corners, and places hard to get at, this may be sponged off at once, but generally it is better to leave it to get cold, as it excludes the air and enables the glue to set more firmly.

Glue is required principally in putting framed work together, and in panels; but the less of it that is used the better, even in fixing.

Two boards may be glued edge to edge, forming a simple butt joint, or their junction may be strengthened by being grooved and tongued as well as glued.

A considerable surface is often covered with boards so united, as in window backs, dados, etc. In such cases keys are generally grooved in across the back, as shown in Fig 177. These keep the surfaces of the boards in the same plane, and allow them to shrink and expand with changes in the weather.

Glued and Blocked Joint.—Two boards at an angle may not only have the joint between them glued, but may also be strengthened by a block glued into the angle, as at *bl* in Fig. 180.

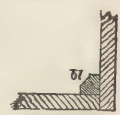


Fig. 180.

Such a construction is called a *glued and blocked joint.* Examples of its use are given at page 164, in the connections of the treads and risers shown in Fig. 243.

For all sorts of curved surfaces small blocks are glued together, and then covered with a veneer.

Sometimes wood is bent to the form required, and then blocks are glued on to the back to keep it so.

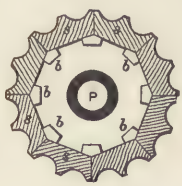


Fig. 181.

In order to avoid using large pieces of timber, which can never be so seasoned throughout as to prevent splitting, columns and similar constructions are built up with thin staves, *s s*, of dry wood, the required support being afforded by an iron column, P, within; and small blocks, *b b b*, are glued inside the joints to strengthen them, as in Fig. 181.

Fixing Joiners' Work.—All joiners' work that is not framed should be fixed so as to be free to expand or contract.

In boarding generally, this may be effected by fixing one edge, and forming the other with a groove and tongue; or the board may be fixed in the centre, with both edges free.

For example, the upper edge of the skirting in Fig. 198 is fixed to the "ground," but the lower edge is free to move, the joint between it and the floor, which would open as the skirting shrinks, being covered by the tongue along the bottom of the skirting which enters the groove formed in the floor. If the skirting board were not thus free to move it would split as it became seasoned.

Again, it will be seen that the frame of the window back (Fig. 198) is free at the lower edge.

The dado in Fig. 185 is also fixed at the upper edge only.

N.B.—In the figures illustrating this section the parts are marked with the following distinctive letters:—

A . . Architrave.
B . . Bracket.
b . . Batten.
ba . . Backing.
bl . . Back lining of sash frame.
bk . . Blocks or blockings.
br . . Bottom rail of sash.
bw . . Weight to balance bottom sash.
C . . Capping.
c . . Cradling.
D . . Dado.
f . . Fillet.
g . . Ground.
H . . Head of sash frame.
h . . Hinges.
SS . . Stone sill.
SL . . Stone lintel.
SF . . Solid frame.
sb . . Sash bar.
sk . . Skirting.
t . . Throating.
tl . . Top lining.
tr . . Top rail of sash.
ib . . Inside bead.
il . . Inside lining of sash frame.
l . . Laths.
mr . . Meeting rails.
ol . . Outside lining of sash frame.
os . . Oak sill.
P . . Plaster.
Pp . . Pocket piece.
p . . Pulley.
pb . . Parting bead.
ps . . Pulley style.
psl . . Parting slip.
RA . Relieving arch.
s . . Styles.
SB . . Surbase.
tw . . Weight to balance top sash.
WB . Wood bricks.
wb . . Water bar.
wp . . Wood plug.
WL . Wood lintel.
WiBd . Window board.
x . . Wedge.
y . . Do.
zps . . Zinc parting slip.

Grounds are pieces of wood nailed to plugs, wood bricks,[1] breeze fixing blocks, or slips in the wall, so as to form a firm basis to which the more ornamental portions, such as architraves, linings, etc., may be fixed.

Grounds are used round the margins of openings not only to receive the linings and architraves, but to form a solid finish to the plastering.

[1] Wood bricks, slips, plugs, etc., have been described at page 11, Part I.

Mitred or Splayed Grounds have the side next to the plastering splayed or bevelled as shown in Fig. 182, so as to form a key for the plaster and secure the joint. This term is often used for grounds which are of a splayed form in plan, such as that in Fig. 201.

Grooved Grounds are those which have the inner edge grooved instead of splayed, to answer the same purpose, *i.e.* that of affording a key for the edge of the plaster.

Examples are given in Fig. 183, and several other figures.

When the joint between the ground and the plaster is covered by an architrave, the splay or groove on the edge of the ground is often omitted, as in Fig. 188. It is, however, better to have it, to form a key for and to secure the plaster firmly until the architrave is fixed.

Finished or Wrought Grounds.—In most cases the ground is rough, its surface being flush with that of the plaster on the walls, and concealed by the architrave fixed to it: sometimes, however, either the whole or part of the surface of the ground is exposed to view; it is then said to be "finished," and is wrought, beaded, or otherwise ornamented.

Fig. 196 shows an example, in which the whole of the ground is visible. In Fig. 200 only part of the ground is seen, which forms the fascia of an architrave, and is embellished by mouldings attached to it.

Framed Grounds are used as margins for openings in superior work.

They form a sort of rough frame, generally concealed from view, and consisting of two upright sides or posts mortised to receive a head terminating in haunched tenons.

Backing.—In order to form a firm support to the lining between the grounds, cross pieces are dovetailed in between the uprights of the adjacent frames, as shown in elevation in Fig. 191 and in plan in several figures; these are firmly attached to wood bricks, whose edges may be seen in elevation behind them (see Fig. 191).

Common Grounds.—In very common work the grounds consist only of the upright posts or styles, and are not framed into a head at all; in other cases a head is provided, but the styles, instead of being framed, are merely halved or notched into it.

Fixing Grounds.—The grounds should be fixed before the plastering is commenced; they form a "screed" or guide, to which the surface of the second coat is floated (see p. 203).

It is therefore important that the grounds should be solidly and accurately fixed, their surfaces and edges should be perfectly true, and so firm that they will not be easily disturbed by the plasterers.

In fixing grounds the face of the ground should project about $\frac{3}{4}$-inch from the naked wall, if it is to be rendered or plastered; or the same distance from the battens, if it is to be battened, lathed, and plastered.

The inner edges of grounds for door and window openings should be kept perfectly plumb, and equidistant from the centre line of the opening, the face of the ground being parallel to that of the door or sash-frame.

The width of such grounds will depend upon their finish; also upon the nature of the opening.

If with linings, the grounds may be from 3 to 6 inches wide, the linings being attached to their edges (Fig. 197). If the grounds are wrought, the architrave or fillet covering the junction of the plaster with the ground may lap over about half the width of the ground (Fig. 197). When boxings are used the grounds will be of sufficient width to contain the shutter and back-flaps required, and may be wrought (Fig. 200) or covered with a double-faced architrave (Fig. 201).

Several examples of grounds are given in pages 129 to 141, and there described, so that it will be unnecessary to enter upon them further in detail at present.

Architraves are borders fixed round the openings of doorways or windows for ornament, and also to conceal the joint between the frame and the plastering.

These borders may be of almost any pattern or dimensions to suit the character of the room.

They are sometimes covered with elaborate mouldings, or made in the form of a pilaster.

The mouldings of the architrave may extend down to the floor as in Fig. 186, or they may rest upon blocks or plinths as in Fig. 190.

The architrave should never be fixed until the plastering is completed and quite dry. It should then be placed so as well to cover the joint (see Fig. 193).

Grounds fixed to the wall are generally provided to form a support to the architrave, and are covered by it (see Fig. 193). But in some cases, as already mentioned, the ground itself forms

the face of the architrave, as in Fig. 194, or in inferior work it may serve all purposes, as shown in Fig. 196.

In order to save labour, and to avoid large pieces of timber, architraves are generally built up in parts glued together. Examples of this will be seen in Figs. 193, 204.

These parts generally consist of a flat portion or base, which is merely a board, beaded, or otherwise ornamented, on edge, and called the face. This is surmounted by mouldings according to taste.

Larger architraves are formed of pieces of different thicknesses tongued together, as in Fig. 188. Those made by machinery may, however, be procured all in one piece.

Double-faced Architrave.—When the base of the architrave is not of equal thickness throughout, but stepped back in the centre, as shown in Fig. 201, it is said to be "*double-faced.*"

Skirtings.—The *Skirting*[1] is a board from 6 inches to 18 inches wide running round the base of the wall of a room. It is intended to cover the junction of the floor with the walls, and also for ornament.

The skirting board may be square or plain, ornamented by a bead or moulding *stuck* upon it (Fig. 182), or by a detached moulding (Fig. 185) it may be sunk to form a double plinth similar to that in Fig. 183. The skirting may be plugged close up to the wall, or fixed to grounds.

These grounds are rough battens nailed to plugs in the wall, and they should be dovetailed at the angles. A narrow horizontal ground, plugged to the wall, runs close behind the top of the skirting; and, if the latter is wide, blocks, placed about 9 inches apart, extend from the floor to this horizontal ground. Such a skirting is seen in Fig. 182, and another in Fig. 184, where it forms the base of a "dado;" a portion of the skirting is stripped off in order to show two of the blocks supporting it.

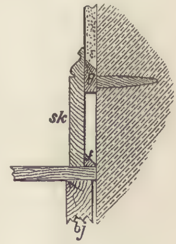


Fig. 182.
Scale, 1 inch = 1 foot.

The lower edge of the skirting is sometimes housed into the floor, as in Fig. 183, or tongued, as shown in Fig. 185; or it may rest upon it, as in Fig. 182; in either case a fillet, *f*, may be added to cover the joint at the back, though this is not absolutely necessary when it is let into the floor. To save material the fillet may be splayed, *i.e.* made of triangular section (Fig. 182).

[1] Sc. *Base*, if mouldings are run upon it.
,, *Base plate*, ,, ,, separate.

When the floor is uneven the lower edge of the skirting must be scribed to fit it—that is, a line is drawn upon it parallel to all the irregularities of the surface of the floor, and the lower side of the skirting is cut to this line.

The skirting boards should be tongued (or dovetailed) at the internal angles of rooms and mitred, as shown in Fig. 164, at external angles,—in either case the top edge of the joint is mitred right through. The skirting boards should also be tongued wherever they are pieced in length.

The hollow behind the skirting harbours vermin, and the plastering should always be continued down to the floor so as to fill it up (Fig. 184).

The boards of skirtings, as in all joiners' work, should be fixed so as to allow of contraction and expansion without splitting.

This may be done by fixing one side of the board, and tonguing and grooving the joint on the other edge.

Several examples of ordinary skirtings may be seen in the figures illustrating other parts of joiners' work, both in this chapter and in Chapter V., some of which have just been referred to.

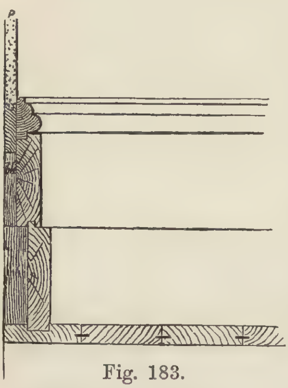


Fig. 183.
Scale, 1 inch = 1 foot.

A Double Skirting consists of two skirtings, one above the other, as in Fig. 183. The width of both skirtings may be equal as in the illustration given. The lower one is sometimes wider than the other, or it may be narrower, according to taste.

Skirtings are often formed in cement and moulded, but such constructions do not come within the province of the joiner.

Dado and Surbase.—For the sake of ornament, and to prevent the wall from being injured by chairs knocked up against it, a moulded bar, called a "chair rail," is sometimes fixed at a height of about 3 feet from the floor, and parallel to the skirting.

This rail should be fixed to a narrow horizontal ground, and should be wide enough to cover the grounds and their junctions with the plastering.

The interval between the rail and the skirting is called the *Dado*, D in Fig. 184, and the chair rail, SB, is called the "*surbase*" of

the dado—the skirting forming the "*base*" B, or, as it is some times called, the *plinth.*

The dado may be either panelled, simply boarded, or formed only by the surface of the plastered wall, as in Fig. 184.

Fig. 184 shows a chair rail or surbase, SB, and plastered dado, D, with wooden "base" or "skirting," B.

The chair rail and the upper moulding of the skirting are nailed to narrow grounds, *g g*, Fig. 184, fixed to plugs inserted in the wall.

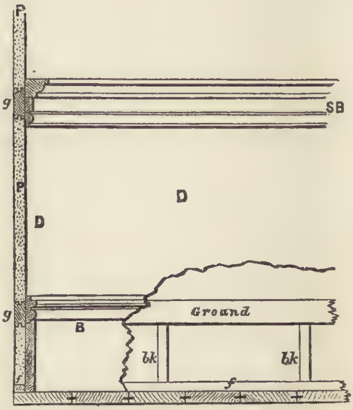


Fig. 184. Scale, ½ inch = 1 foot.

A portion of the skirting is broken away to show the blockings, *bk*, supporting it as described at page 126.

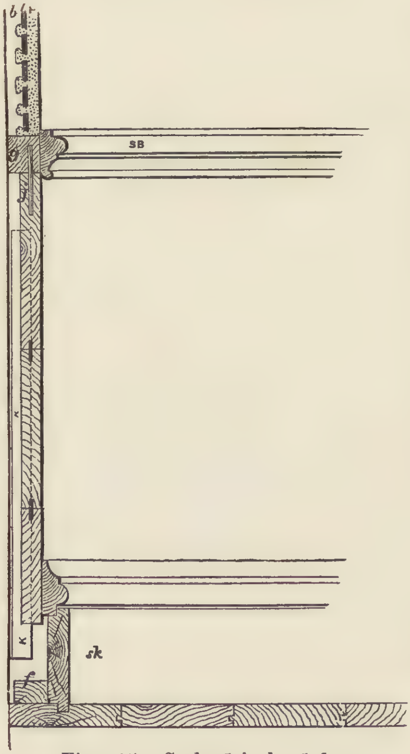


Fig. 185. Scale, 1 inch = 1 foot.

The dado illustrated in Fig. 185 is entirely of wood, being formed of wide boards, grooved and feathered, and hung by thin tongues of hard wood, *j*, at intervals of about 3 feet, to the narrow ground, *g*, which supports the surbase, SB. The boarding is strengthened and kept together by taper keys, *k*, similar to that described at page 121.

The keys may be about 3 feet apart.

The boarding of the dado is thus suspended from the upper "ground," and is free to expand and contract without opening the joints.

LININGS.

Linings are coverings of wood so placed as to conceal or ornament portions of the interior of buildings. There are several varieties of linings, distinguished by technical names denoting the position in which they are fixed.

All linings should be of narrow boards, ploughed or grooved and tongued, or rebated; free to expand and contract, and nailed to battens fixed to the wall about 2 feet apart.

In superior rooms the linings may be framed and panelled as described at page 76, Chap. V.

Linings to Doorways.—*Jamb Linings* cover the sides of the jambs or openings through walls, such as doorways.

Soffit Linings are those which cover the soffit or under sides of the arch or lintel spanning over a door, or the interior of a window opening.

Window Linings are differently named according to their position.

Breast Linings are those that cover the portion of the wall between the inside ledge or window board and the skirting. These are more commonly called "*window backs.*"

Elbow Linings cover the splays of the wall between the inside ledge or window-board and the skirting when there are no shutters (see Fig. 197).

Back Linings are those at the back of the recesses for shutters (Fig. 200). This name is also given to that side of the boxing in a cased sash frame which is opposite the pulley stile (see p. 105, Chap. V.)

The Outside and Inside Linings are those forming the outer and inner sides respectively, of the boxings in cased sash frames.

Wall Linings are of the same nature as the above, but cover the whole surface of the walls.

Jamb and Soffit Linings.—In doorways the sides or "*jambs,*" J J, and the "*soffit,*"[1] S S, of the opening are generally boarded over or lined for the sake of appearance.

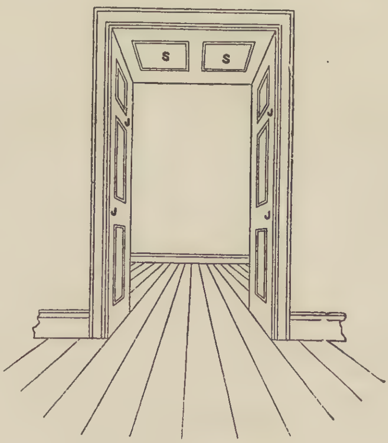


Fig. 186.

[1] Sometimes called *Jamb-head.*

This boarding is called the jamb and soffit linings. These linings serve to conceal the rough sides and soffit of the opening beyond the recess containing the frame. If more than 9 or 10 inches wide they should be panelled, moulded, or otherwise made to correspond in appearance with the face of the door.

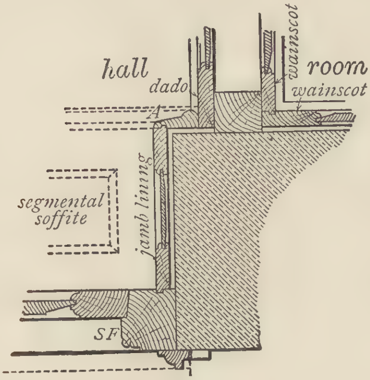


Fig. 187.

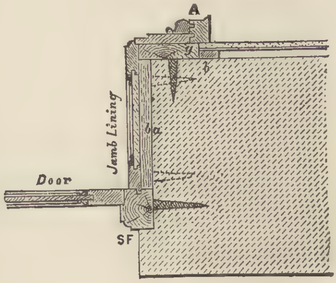


Fig. 188. Scale, ½ inch = 1 foot.

Jamb Linings to external Doorway.—It has been mentioned that external doors are nearly always hung in solid frames. If the doorway is in a thick wall, and for any reason it is required to keep the door near the front of the wall, there remains a considerable depth of the opening behind it which may be lined.

Such cases are shown in Figs. 187, 188. The lining in these examples is very simple, consisting merely of a 1-inch framed, moulded and square, panelled lining, flush at back, tongued into the door frame at one end, and at the other butting against the architrave A. The lining in Fig. 188 is supported by a rough backing fixed to plugs in the wall.

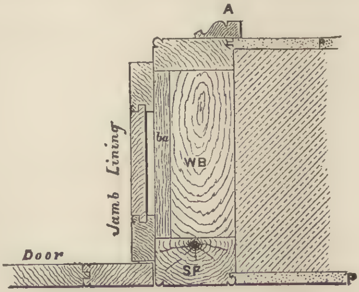


Fig. 189. Scale, 1 inch = 1 foot.

Solid Frames with Jamb Linings for internal Doorways.—In this case the jamb lining is kept back from the edge of the frame a space equal to the thickness of the door, thus forming a deep rebate into which the latter may shut.

The lining is fixed as before to a rough backing, *ba*, which is secured to wood bricks or slips in the wall.

This is a very strong way of hanging a door, but is expensive and seldom adopted for interior doors, unless very heavy and substantial work is required.

The solid frame may be beaded or chamfered on both edges and itself form the finish of the doorway, as at SF, Fig. 189; or the joint between it and the plaster may be covered by an architrave, as at A on the opposite side.

The lower ends of the frame may be tenoned into the floor, which keeps it very firm.

Jamb Linings with framed Grounds.—This is the most usual way of hanging a door in ordinary work.

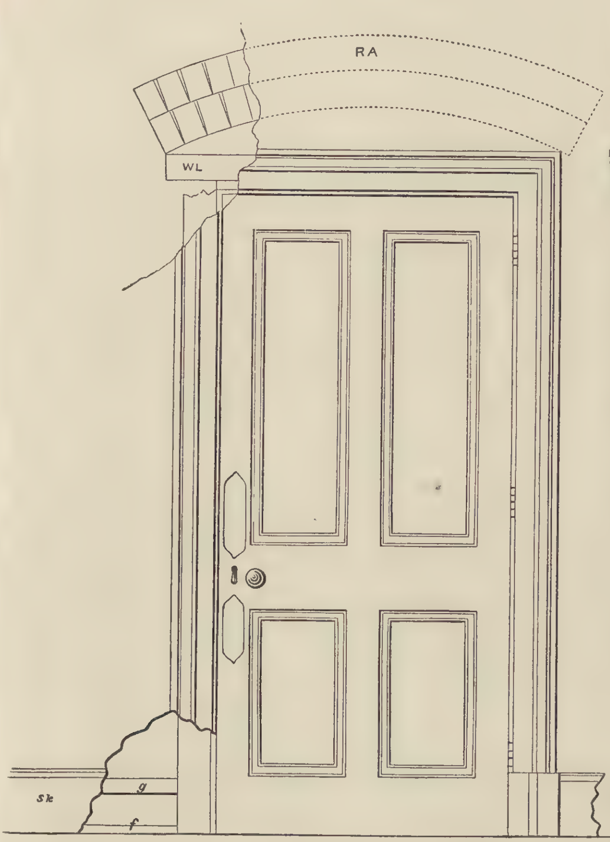


Fig. 190. *Elevation.*

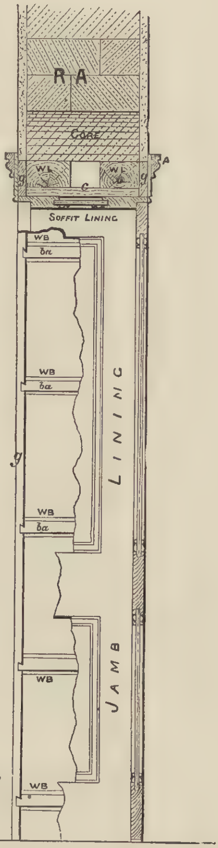


Fig. 191. *Section.*

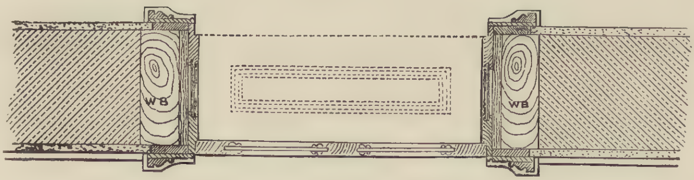


Fig. 192. *Plan.*

Figs. 190-192. Scale, $\frac{1}{2}$ inch = 1 foot.

Figs. 190, 191, 192 give an elevation, cross-sectional elevation, and plan respectively, of a four-panelled interior door, with jamb

and soffit lining of this kind. Fig. 193 shows a portion of the plan enlarged.

In this case it will be seen that the door is hung to the jamb lining itself; the latter is attached to a backing, *ba*, dovetailed in between the framed grounds, and secured to wood bricks in the wall, the edges of which may be seen in elevation in Fig. 191.

In some cases the grounds are tongued into the jamb linings, but this is very seldom done.

The jamb linings go right through the depth of the opening, and on one side of the wall have their edges rebated to receive the door; the edges on the other side of the wall being (in superior work) similarly rebated to correspond.

The soffit lining is secured to cradling or backing, *c*, consisting of rough battens attached to the under side of the lintels over the opening.

Of course the doorway might be spanned by a rough axed arch, or by a concrete beam, without wood lintels, in which case the cradling would be secured to plugs let into the arch or beam, unless the beam were made of coke breeze concrete which will admit and hold nails.

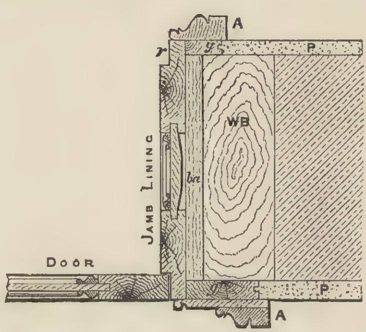


Fig. 193. Scale, 1 inch = 1 foot.

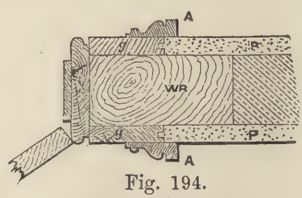


Fig. 194.
Scale, 1 inch = 1 foot.

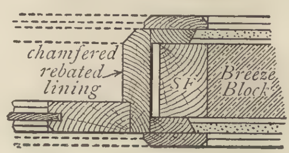


Fig. 195.

The enlarged plan in Fig. 193 differs slightly from Fig. 192, inasmuch as a smaller architrave is shown on the inside of the doorway. The panelling of the soffit lining is often shown in dotted lines upon the plan of the doorway.

Fig. 194 shows the jamb linings, with framed and finished grounds for a doorway in a thin partition wall. In practice, however, a solid frame would be preferable as in Fig. 195. It would run up and be secured to the joists over.

Jamb Lining with finished Grounds.—In common work—to save the expense of architraves—the grounds may be wrought so as to present a finished appearance, and themselves form an ornamented margin to the opening.

In Fig. 196, *g* is a wrought and chamfered ground secured to the backing *ba*, which is plugged to the wall. It will be seen that *g* acts both as a ground and as an architrave. This is taken from an actual case, but has little to recommend it, as the ground really forms only a feeble sort of door frame.

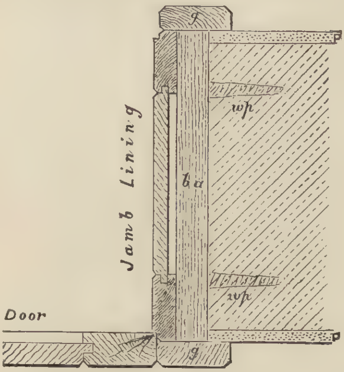


Fig. 196. Scale, 1 inch = 1 foot.

Single and Double rebated Linings.—Single-rebated linings are those having a rebate formed to receive the door, but none on the other side of the wall. In superior work there is a similar rebate formed on the opposite side, as at *r* in Fig. 193, and the lining is said to be *double-rebated.*

Window Linings.—Figs. 197, 198 give a half-plan and a section of a window with cased frame and double-hung sashes, furnished with panelled and moulded linings.

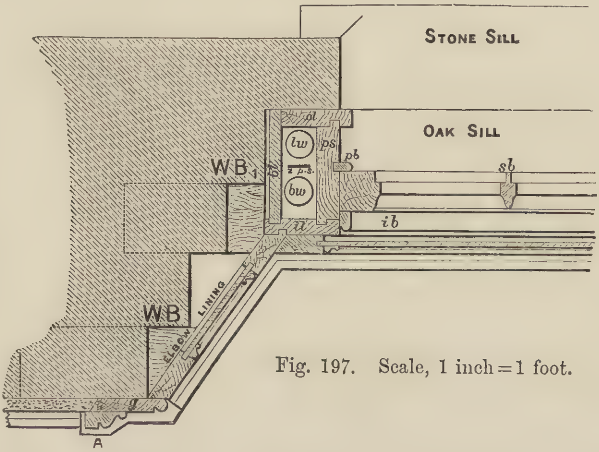


Fig. 197. Scale, 1 inch = 1 foot.

It will be noticed that the head of this window is not cased as in the illustrations given of windows without linings (Fig. 137), but is solid, being secured to the cradling *c* attached to the under side of the lintels, WL, its inner side being grooved to receive the tongued extremity of the soffit lining, the other side of which is nailed to the ground.

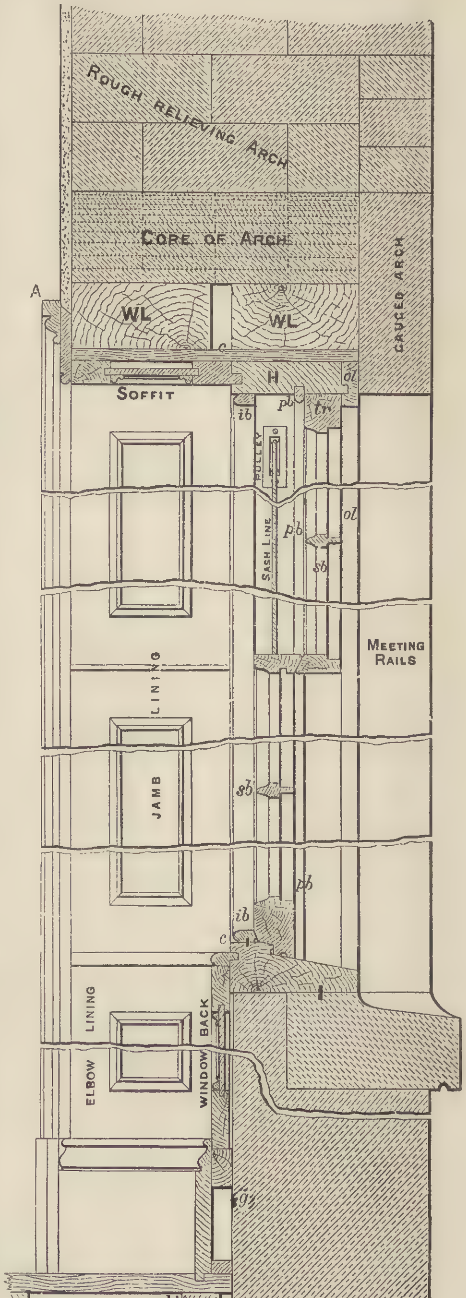
The jamb lining is grooved at one end into the inside lining of the boxing, and at the other nailed to the projecting framed and finished ground which forms the face of the architrave

It is supported by being nailed to the splayed wood brick, WB.

The upper rail of the window back is secured to the oak sill, being surmounted by a capping *c*. The lower rail rests upon the ground *g*, the joint being covered by the moulding of the skirting,[1] so that the expansion and contraction of the window back are not prevented.

The jamb lining is here shown as finished to look like shutters, sometimes described as "*sham shutters.*" When the lining is narrow it is often merely a plain board, tongued if the width requires it, wrought on face, but not framed; when moulded it is made to correspond in appearance with the doors or other panelled work of the room.

The wood brick, WB_1, is inserted in this case, so that the boxed frame may be nailed to it obliquely through the inside lining, *il*, but it is generally considered sufficient to drive a wedge in between the back lining and the wall.



Vertical section through centre of Fig. 174.
Fig. 198. Scale, 1 inch=1 foot.

[1] In practice it is more usual to frame the window back and elbows with flush beaded skirting: (1) To avoid the difficulty of stopping the projecting skirting against the architrave; (2) In order to make the framing from floor upwards in one piece. The flush bead ranges with the top of the ordinary skirting.

SHUTTERS.

Windows, especially those of ground-floors, are frequently fitted with shutters for security and warmth at night.

Inside Shutters are fixed on the inner side of the wall of a building.

Outside Shutters are fixed on the outer side of the wall.

Inside Shutters are hung in several different ways, which may be generally arranged under two heads.

1. *Folding.*—In leaves, hinged together and folding back into recesses or "*boxings*" prepared for them.

2. *Sliding.*—In leaves, sliding up and down, and counter-balanced by weights in the same way as sliding sashes; or sliding *laterally* upon rollers in and out of recesses formed for them at the sides of the window.

FOLDING SHUTTERS.—A recess or boxing for these is formed in the space between the inside lining of the sash frame and the framed ground at the back of the architrave.

The back of this recess is plastered in common work, but in better work it is covered by a lining, called the "back lining."

This back lining has one end tongued into the inside lining of the sash frame, and the other housed or tongued into the ground behind the architrave.

In Fig. 200 the architrave is fixed to a finished ground into which the back lining is grooved.

As the interior of the boxing is exposed to view when the shutters are closed, the back of the ground is sometimes covered, for the sake of appearance, by a return lining such as that marked *l* in Fig. 201.

The leaf which is exposed to view during the day may be framed and panelled like the doors of the room, and is called the *shutter*, the remaining leaves are called the *back flaps*.[1]

The back flaps, if they exceed 6 or 7 inches in width, are framed, but may be of a plainer description of panelling, or sometimes not panelled at all.

In most of the accompanying illustrations the shutter and flaps are shown as framed square on the outer side and bead flush on the inner side. The inner side is often finished bead butt for the sake of economy; or the flaps are often framed square

[1] Sc. *Backfolds—Closers.*

on both sides, or moulded on one or both sides according to the class of work.

In the very best work, however, the shutters and flaps are all made the same on both sides, so that when closed they will all appear alike, whether seen from the interior of the room or through the glass from the outside.

In hanging shutters the knuckle of the hinges of the front leaf should be about half-an-inch from the inner angle of the inside lining—so that the whole width from one extremity of the shutters to the other, when they are open, is an inch more than the width of the window opening.

The flaps are connected by small "back-flap" hinges fixed as shown, or by butt hinges attached to the edges of the flaps. In the former case the shutters, when folded back, are kept apart by nearly the thickness of the hinge, and there is room for an iron bar or other fastening to hang between them.

Shutter and One Flap.—When the opening is narrow, or the wall of considerable thickness, the shutter may be hung in two leaves, as in Figs. 199, 200.

Fig. 199 is an interior elevation of a window with sliding sashes fitted with shutters hung in two leaves. The shutter and

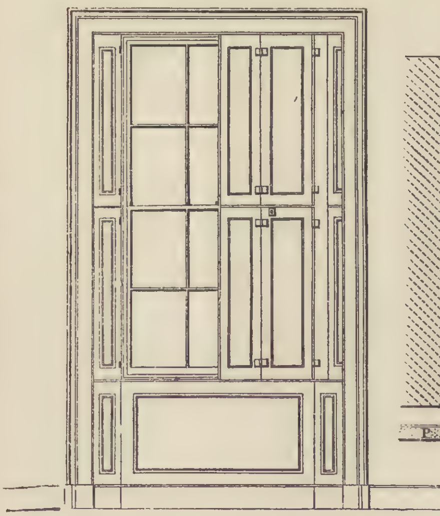


Fig. 199. Scale, ¼ inch = 1 foot.

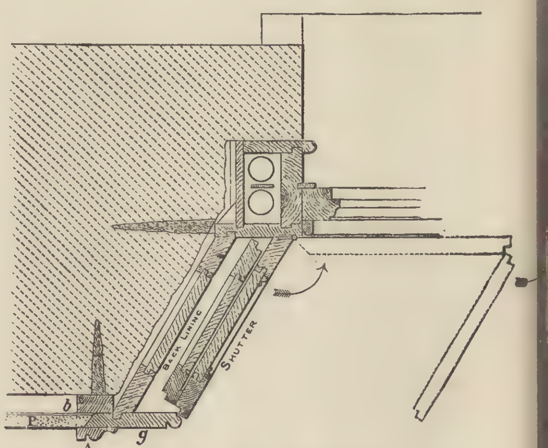


Fig. 200. Scale, 1 inch = 1 foot.

flap to the right of the elevation are closed, the other shutter and

flap being folded back into the boxings, as shown in the half-plan Fig. 200.

The shutter is moulded on the side exposed to view during the day; the back of this shutter and that of the back flap (which are seen together on the inside of the room when the shutters are closed) are bead flush, while the front or outer side of the back flap is framed square.

In this and some of the following figures the dotted lines show the position of the shutters and flaps while in the act of being closed.

Shutter and Two Flaps.—When a window opening is wide, or the wall in which it is formed is not very thick, there is not so much room for shutters in proportion to their width, and they have to be folded into a greater number of leaves in order that they may take up less room in the thickness of the wall.

Fig. 201 is the half-plan of a window with the same opening as that in Fig. 200, but in a wall only 1 foot 6 inches, instead of 2 feet thick.

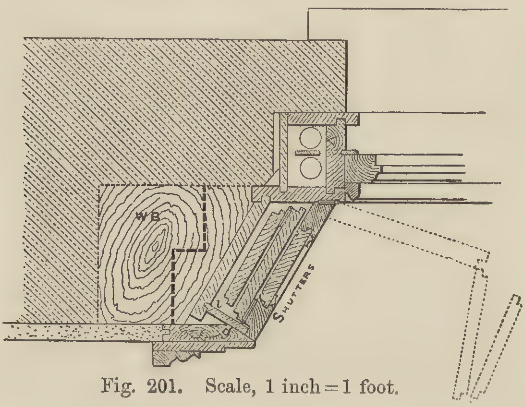


Fig. 201. Scale, 1 inch = 1 foot.

The shutter in this case is necessarily folded into three leaves; the two back flaps being very narrow are not framed.

The lining, *l*, at the back of the ground, *g*, is only to preserve a neat appearance within the boxings when they are empty; it may be omitted and the back lining of the boxing prolonged to meet the back of the ground.

There are many methods of arranging folding shutters, which vary considerably according to the length of shutters required — and the space available for them to fold into.

One method of gaining room for shutters is to make the boxings project into the room, as shown in Fig. 202, or when the

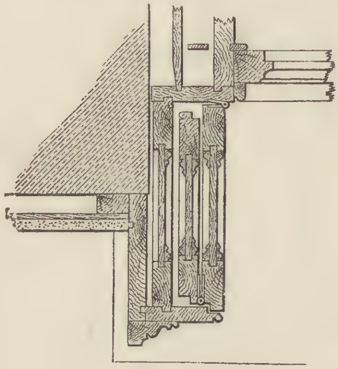


Fig. 202. Scale, 1 inch = 1 foot.

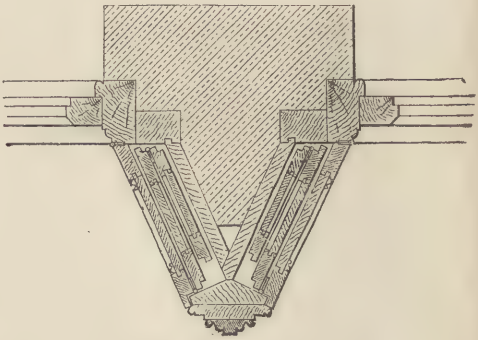


Fig. 203. Scale, 1 inch = 1 foot.

windows are separated by very narrow piers, the shutters may be arranged as in Fig. 203.

Where the masonry cannot be made to extend inwards far enough to form a support for the lining at the back of the shutters, such support is afforded by wooden brackets fixed to the back of the pier and extending inwards as far as may be required.

Another arrangement for shutters to cover a window in a thin wall is shown in Fig. 204.

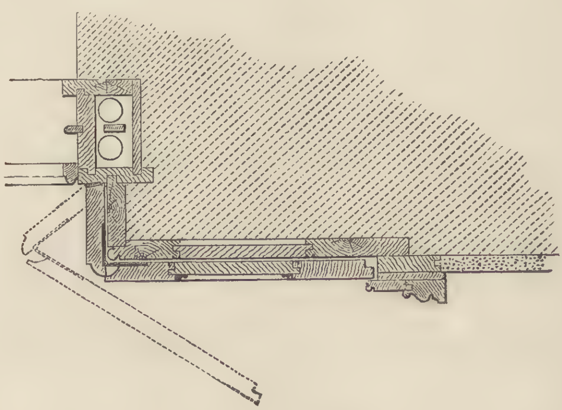


Fig. 204. Scale, 1 inch = 1 foot.

In this case the larger flap of the shutter folds back upon the inner side of the wall, and is exposed to view, being connected with the boxing of the window by a short flap which forms the jamb

lining. The elbow of the wall is lined, in order to present a neat appearance when the shutters are closed.

This is rather an old-fashioned arrangement, but very useful in some situations.

Shutters with Cover Flap.—The different forms of folding shutters hitherto illustrated have one disadvantage in point of appearance, viz., that when the shutters are closed the recess formed to receive them is visible, and forms a break in the continuity of the panelling.

To avoid this, in very superior work the recess is covered by a separate flap, X (Fig. 205), which is hinged to the ground supporting it. When the shutters are to be closed, this flap is opened; and after they are shut against the sash the flap is returned, so that the appearance of the lining is preserved intact.

In order to throw the shutters back into the recess sufficiently to clear this flap, various arrangements are adopted.

That shown in the figure simply consists of a hinge, *h*, of peculiar form attached to a heavy moulding fixed to the inside lining of the cased frame. The action of this hinge will be clear upon examining the figure, in which the shutters are shown folded back into the recess, the position, X_1, of the flap, when partly closed, being indicated in dotted lines.

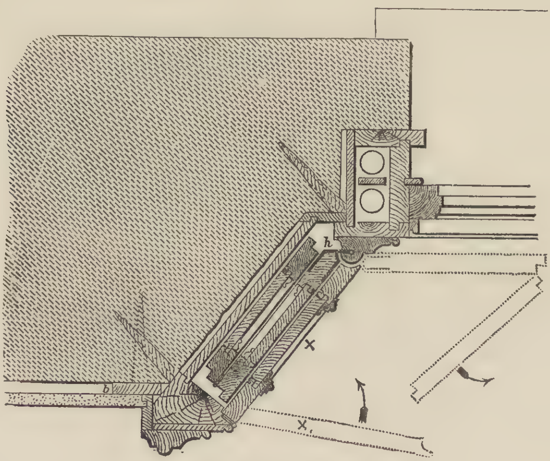


Fig. 205.[1] Scale, 1 inch = 1 foot.

In some cases the shutter is thrown back clear of the covering flap by inserting a very short flap,[2] which lies across the ends of

[1] Modified from Plate 54, vol. iii., Laxton's *Examples of Building Construction.*

[2] A good example of this arrangement is shown in Laxton's *Examples of Building Construction*, Plate 55, vol. iii.

the shutters nearest the sash frame, and answers the same purpose as the peculiar hinge shown in Fig. 205.

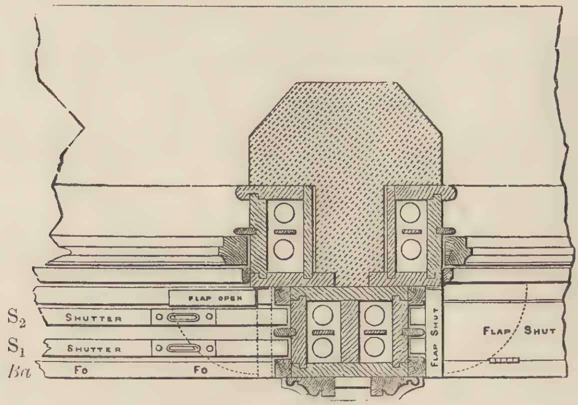


Fig. 206. Scale, 1 inch = 1 foot.

Sliding Shutters may move either vertically or laterally, in the former case they are often called *lifting shutters.*

Lifting Shutters are hung in exactly the same way as sliding sashes; immediately behind the boxed frame of the sash is a similar frame for the shutters (Fig. 206).

The leaves of the shutters slide down into a rectangular well formed for them in the floor, so that their upper rails are nearly level with the window sill.

On the front side they lie close to the inside of the wall, and on the other they are screened by a framed *back* (*Ba* in Fig. 207).

The two leaves of the shutter slide in different and parallel paths,—the upper one, S_1, between the bead on the front lining of the shutter frame and the parting bead; the other, S_2, between the parting bead and a bead fastened on to the inside lining of the sash frame.

The shutter nearest to the wall, S_2, is the lower of the two when they are closed. It is somewhat larger than the other, being of such a height that it will extend from the top of the flap or capping to the upper edge of the meeting rail. The other shutter fills up the space between the upper edge of the meeting rail and the top of the window.

The top of the well is closed when the shutters are down by a horizontal hinged flap, and vertical flaps conceal the parting bead, etc., when the shutters are not closed.

Sliding shutters are useful when there is not a sufficient thickness of wall behind the sash to receive folding shutters.

Fig 206 is a plan of part of two adjacent windows separated by a narrow pier or mullion, and fitted with lifting shutters, and Fig. 207 is a veitical section of the same.

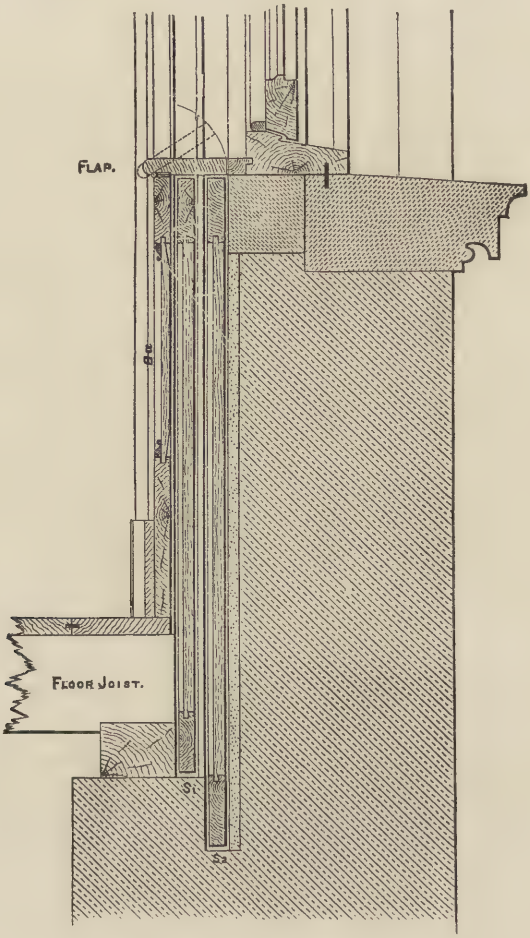


Fig. 207. Scale, 1 inch = 1 foot.

On the left of the plan the flap over the well for the shutters is supposed to be standing vertically open along FO FO, so that the upper rails of the shutters are visible with the flush handles for lifting them.

The vertical flap is also open and folded back.

On the right of the figure both flaps are closed.

In some cases the boxing for shutters is so arranged that its outside lining is formed by the inside lining of the cased frame for the sashes, which is a more economical construction than that shown in Fig. 206, but not so convenient.

Sliding Shutters are those in which the flaps slide laterally into recesses formed on each side of the window.

Such an arrangement can only be adopted when there is a considerable space on each side of the window. It possesses no particular advantages, and cannot here be described.

A good illustration of shutters sliding laterally will be found in Laxton's *Examples of Building Construction*, vol. iii., Pl. 37.

Outside Shutters for dwelling-houses are generally hung somewhat like doors—in two leaves, one on each side—which are fixed to the outside lining (or to a fillet plugged to the wall in front of the outside lining) with *parliament hinges*, by which it is enabled to clear the reveal, and fold back upon the wall; see Fig. 208.

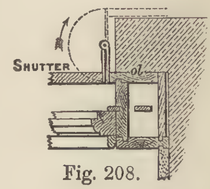


Fig. 208.

For shop fronts shifting shutters, or revolving shutters on rollers, are used, the appearance of which is familiar to all. Any description of them would be beyond the range of these Notes.

SKYLIGHTS AND LANTERNS.

Skylights are windows, either fixed in roofs, or themselves forming the roof of a staircase or other building lighted from above.

They are very varied in form, according to the position in which they are fixed.

In many cases the skylight is raised upon vertical or slightly inclining frames filled in with sashes which form its sides (Figs. 213, 214); it is then frequently called a *Lantern*.

The most common form of skylight is perhaps that in which the sash is parallel to the slope of the roof, and slightly raised above the surface of the slating as in Fig. 209.

An opening is formed in the slope of the roof (by trimming the common rafters CR), of the same size as the proposed skylight; a lining[1] is attached to the inner sides of the trimmers TT, and of the trimming rafters, extending a few inches above them. Upon this the sash rests; its styles and rails project over the

[1] Usually called a "*curb*" or "*kerb*," and dovetailed at the angles.

frame, and may be rebated to fit it, or a projecting piece may be nailed on, as shown at *c* in Fig. 209, to cover the joint.

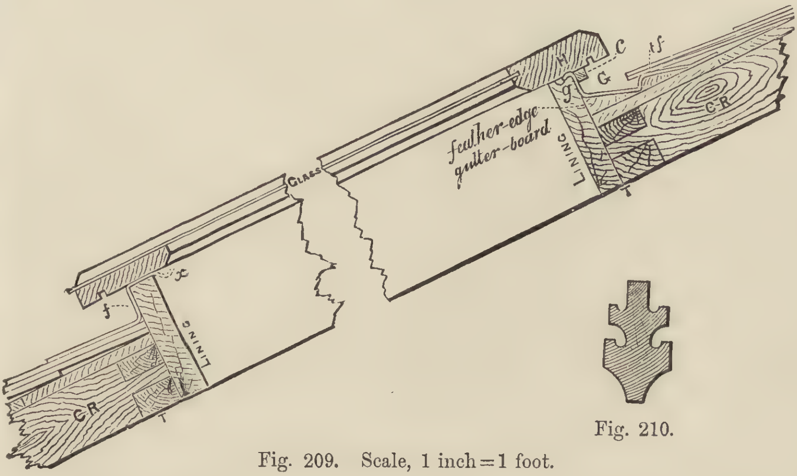


Fig. 209. Scale, 1 inch = 1 foot.

Fig. 210.

Lead flashings, *ff*, are also fixed as shown to prevent the wet from getting in; and any that may penetrate finds itself in a groove *g* cut in the upper surface of the top and side linings, down which it runs, escaping at the lower end of the latter.

The sash bars run down the slope of the roof like rafters, and should be made strong enough to resist the weight of glass and snow, force of wind, etc. The rebates should be grooved, so as to carry off any moisture that may pass round the edges of the glass.

The lead apron at the lower extremity of the inside of the skylight should be formed into a sort of gutter, as shown in dotted lines at x, to receive and carry away the moisture which condenses on the lower surface of the glass. It is also desirable to form gutters in the sides of the sash bars for the same purpose, as in Fig. 210.

The panes should run continuously through from top to bottom of the skylight, without cross bars to intercept the wet running off the glass.

If it be necessary to have the panes in shorter lengths, they should overlap, as in Fig. 211, and be secured by metal clips, shown in thick black lines which hang the bottom edge of each pane to the top edge of the pane below it.

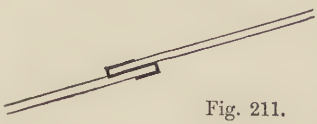


Fig. 211.

It is sometimes necessary, for want of space, to obtain more light, or for other reasons, to make the side linings vertical instead of at right angles to the rafters as shown, but the latter is the stronger construction.

It is becoming usual, especially where a skylight is of considerable length, to avoid the gutter by lowering the head H of the skylight 2 or 3 inches below the lower edge of the slates of the roof. The end at x remains at the same level, so that the slope of the skylight is flatter than that of the roof.

If such a skylight as that shown in Fig. 209 be required to open it must be hinged at H; and in some cases the joint is protected by a strip of lead fastened round the sash, which hangs down over the lead flashing on the sides of the frame.

The glass in skylights is sometimes secured by means of a capping fixed to the upper surface of the sash bars, which holds the glass more firmly and prevents the wet from penetrating.

Another kind of skylight consists of a pair of sashes fixed above the apex of a roof and parallel to its sides.

Two varieties, surmounting a queen-post roof, are shown in Figs. 212, 213.

The skylight, of which half is shown at A, consists of a pair of sashes similar in construction to that just described, raised a few

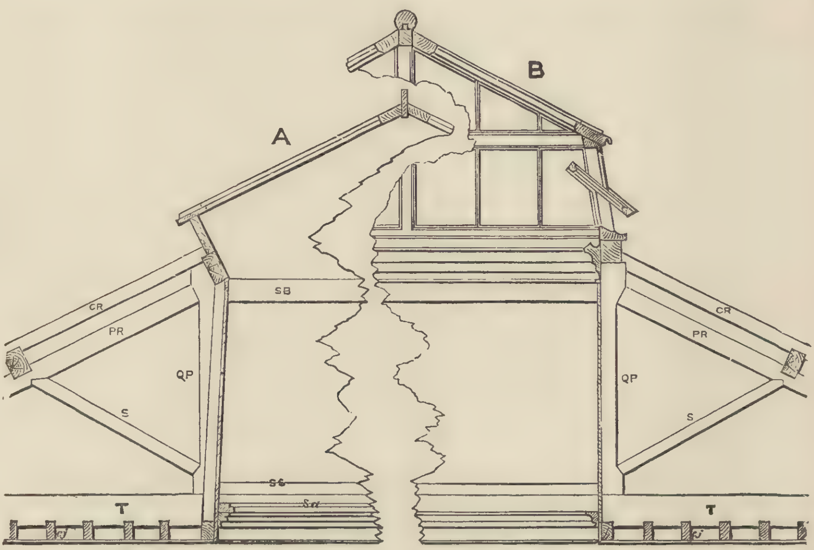


Fig. 212. Scale, $\frac{1}{8}$ inch = 1 foot. Fig. 213.

inches above the surface of the side slopes of the roof by means of linings fixed to the purlins resting upon the queen posts.

The inner sides of the queen posts have backing pieces fixed to them, carrying a lining so as to convert the interval immediately under the skylight into a shaft or boxing.

In some cases, for the sake of appearance, the lower extremity of this shaft is filled in with a sash, *Sa*, called a *counter skylight* or *ceiling light*, containing glass, so as to keep the plane of the ceiling almost unbroken.

The skylight or lantern at B is raised two or three feet above the roof by means of framed sides containing sashes, which may either be fixed, or made to open by being hinged at the top, or (as in Fig. 213) hung on centres.

The sill of the framed sides is fixed to a capping or curb, which rests upon a cross bearer supported by the heads of the queen posts.

This form of skylight gives more light and ventilation than that at A, but is of course considerably more expensive.

Fig. 215 shows a skylight or lantern over a room covered by a lead flat.

This example is taken from the lecture-theatre of an hospital near London, but is in many particulars similar to one over the Museum of Economic Geology, and illustrated in Laxton's *Examples of Building Construction.*

The lantern being large and heavy is supported on two sides by cast-iron girders, AB, CD (Fig. 215), extending across the room. The other sides are covered by binders fixed between these girders.

Fig. 215 is a plan showing the arrangement of these girders, and of the binders and joists supporting the lead flat, the larger portion of which is broken away to show the bearers beneath.

Fig. 214 is a sectional elevation of half the lantern, showing the different parts in sufficient detail to render much explanation unnecessary. The moisture condensed upon the inside of the upper portion of the skylight runs down and is caught in a small zinc gutter formed in the upper portion of the moulding at W, and from thence is led through a hole (dotted in the figure) to discharge upon the lead flat outside.

The details of the side sashes hung on centres are similar to those already given for such sashes in Fig. 132, Chap. V.

It will be noticed that the inside bead, *x*, Fig. 214, is so fixed upon the sill that the skylight when closed does not shut up against it, but an interval is left, which forms a gutter to receive the condensed moisture from the sash. A groove cut in the sill enables this water to escape.

Such a lantern as that shown in Fig. 214 may itself form the roof of a staircase, in which case the oak sill, forming the base of the sash, would rest upon the coping of the walls of the staircase.

When the side sashes of a lantern are fixed, ample provision should be made for carrying off the moisture which condenses on the inside of the glass, and has a tendency to run down into the room below.

This may be prevented by providing a wide oak sill projecting

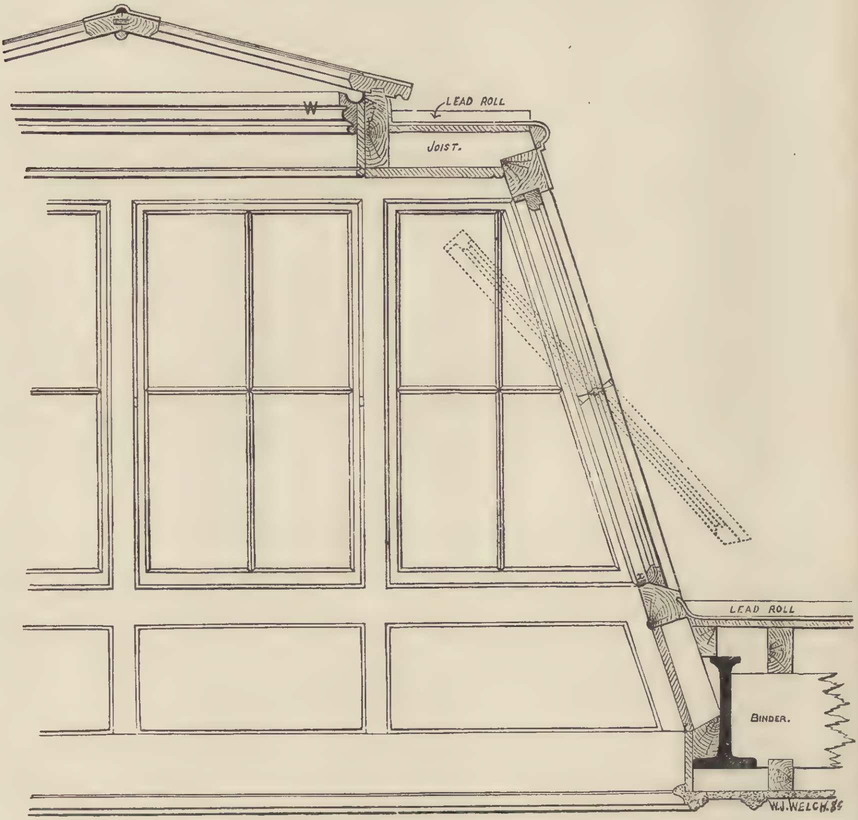


Fig. 214. Scale, 1 inch = 1 foot.

inwards an inch or two, so as to give room for a deep groove formed on the inside, into which the condensed moisture runs, and from whence it is led outwards by holes bored through the sill.

Or the inside bead on the oak sill may be kept a little back from those on the sides, so as to form a gutter as explained above and shown in Fig. 214.

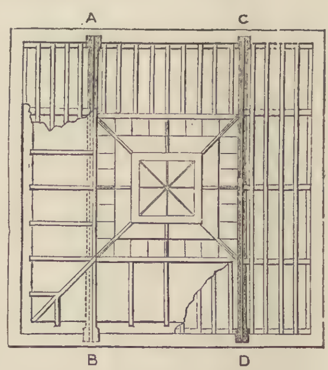


Fig. 215. Scale, $\frac{1}{12}$ inch = 1 foot.

Sliding Sash in Skylight.—It is sometimes advisable to con-

struct the slightly inclined sashes of a skylight so as to open by sliding.

In such a case it is important to keep the rain from penetrating between the frame and the sash.

This may be done by arranging as in Fig. 216.

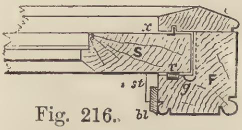


Fig. 216.
Scale, 1 inch = 1 foot.

The sash, S, slides down the frame, F, upon a little brass friction roller, *r*, fixed in the frame. *st* is a stop on the sash which strikes against the block, *bl*, attached to the frame, and arrests the fall of the sash when it has gone far enough.

c is a capping protecting the upper surface of the joint between the sash and frame. As an additional precaution an angle-iron water bar may be inserted as shown, so as to prevent any water running off the sash from penetrating sideways at the point *x*. If, in spite of this, any water should penetrate, it will find itself in the groove *g*, which leads it off through the lower end of the frame.

CHAPTER VII.

STAIRS.

Stairs are arrangements of steps for conveniently ascending and descending from one level to another.

They are generally constructed either in stone, wood, concrete, or iron.

The consideration of iron stairs does not come within the range of these Notes.

The terms common to all stairs will first be mentioned, and also a few general principles universally applicable; after which the construction of stone and wood stairs respectively will be considered more in detail.

The following are terms used in connection with all stairs, whatever may be the material of which they are constructed.

The Staircase is the chamber or space which contains the stairs.

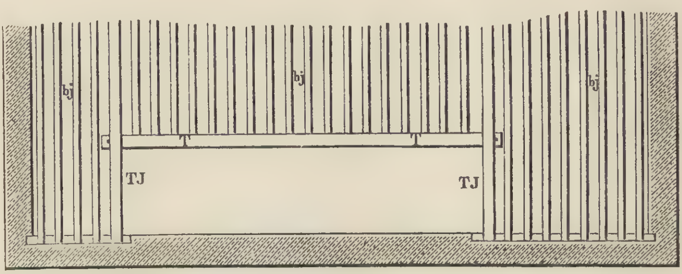


Fig. 217.

This may be a room of the exact size required, the walls of which closely surround and support the steps, as in Fig. 251, or the stairs may be in a large apartment, such as a passage or hall, openings being left in the upper floors so as to allow headway for persons on the steps, and to furnish communication between the stairs and the different stories of the building.

In such a case the stairs are generally, though not necessarily, placed against a wall, as shown in Fig. 217, and the opening is trimmed round in the manner explained at page 130, Part I.

In Factories, or similar large buildings, the staircase should be in a tower projecting from the building, so that it may in case of fire be intact. The best materials for fireproof stairs are, first, mild steel, then cast iron, then hard wood with plastered soffit. With regard to stone steps, see note, p. 152.

Tread is the horizontal upper surface of the step upon which the foot is placed.

Rise is the vertical height between two treads.

Riser [1] is the face or vertical portion of the step.

Nosing is the outer edge of the tread. In most cases it projects beyond the face of the riser and is rounded or ornamented by a moulding, being known, accordingly, as a "rounded" or "moulded" nosing.[2] (See Figs. 219, 239.)

Fliers are the ordinary steps of rectangular shape in plan.

Winders [3] are the steps of triangular or taper form in plan, required in turning a corner or going round a curve. The small ends of winders are sometimes called the *quoins.*

A Curtail Step is described at p. 173.

A Flight is a continued series of steps without a landing.

A Landing [4] is the flat resting-place at the top of any flight

A Half Space is a landing extending right across the width of the stair.

A Quarter Space is a landing extending half across the width of the staircase.

The Going of a Stair is the horizontal distance from the face of one riser to the face of the next riser, and does not include the nosing or the projection of the tread beyond the face of the riser.

This term is, however, sometimes taken to mean the width of the stair, that is, the length of the steps.

The Going of a Flight is the horizontal distance from the first to the last riser in the flight.

The Line of Nosings is tangent to the nosings of the steps, and thus parallel to the inclination of the stair.

Newels are posts or columns used in some kinds of stairs to receive the outer ends of steps. (See Figs. 246, 247.) The name "newel" is sometimes applied to the final baluster on a curtail step.

When the newels surround a central opening, as in Fig. 249, the staircase is said to have an "*open newel.*"

The Handrail is a rounded or moulded rail, parallel nearly throughout its length to the general inclination of the stair, and at such a height from the steps as to be conveniently grasped by a person on the stairs.

Balusters are slight posts or bars supporting the handrail.

Dimensions of Stairs.—The dimensions of staircases and steps are regulated by the purposes for which they are intended.

Length of Steps.—Sometimes spiral staircases are constructed in very cramped positions, with steps only 1 foot 9 inches long; but, as a rule, steps should not be less than from 3 to 4 feet long,

[1] Sc. *Breast.* [2] Sc. *Bottled* or *Bottle-nosed step.* [3] Sc. *Wheeling steps.* [4] Sc. *Plat.*

so as to allow two people to pass, and in superior buildings they are very much longer.

The stairs in the illustrations given with these Notes are necessarily shown narrow for want of space.

Tread and Rise.—The angle of ascent for a stair will depend upon the total height to be gained between the floors, and the space that can be afforded in plan.

The wider the step the less the rise should be, as steps which are both wide and high require a great exertion to climb.

Authorities differ slightly as to the proportion between the tread and riser; the following table is given by Mr. Mayer in Newland's *Carpenter's and Joiner's Assistant.*

Treads, inches.	Risers, inches.	Treads, inches.	Risers, inches.
5	9	12	5½
6	8½	13	5
7	8	14	4½
8	7½	15	4
9	7	16	3½
10	6½	17	3
11	6	18	2½

The following rule is often adopted for steps of the dimensions ordinarily required in practice, *i.e.* those with treads from 9 inches to 14 inches wide:—

Width of tread × height of riser = 66 inches.

Thus with a tread of 12 inches riser would be 5½ inches; with a riser of 6 inches the tread would be 11 inches.

The rule adopted in France, where they have given great attention to the subject, is as follows:—"Inasmuch as on the average human beings move horizontally 2 feet in a stride, and as the labour of rising vertically is twice that of moving horizontally, the width of the tread added to twice the height of the rise should be equal to 2 feet."

The proportion that the tread and riser bear to one another cannot always in practice be fixed by rule, but is regulated by the space—as regards both plan and height—that can be afforded for the staircase.

The tread of a step should, however, never be less than 9 inches in width, even for the commonest stair; while, for first-class houses and public buildings, the stairs may have treads from 12 to 14 inches wide.

Flights should, when possible, consist of not more than 12 or

13 steps, after which there should be a landing, so that weak people may have a rest at short intervals.

Two consecutive flights ought not to be in the same direction (see p. 176).

DIFFERENT FORMS OF STAIRS.

N.B.—In the Figures connected with stairs the handrail is drawn in the elevations and sections in order more clearly to show the direction of the steps, but omitted from the plans so as not to obscure them.

A Straight Stair is one in which all the steps are parallel to one another and rise in the same direction—thus a person ascending moves forward in a straight line.

Figs. 221, 222, 244, 245, show plans and sections of straight staircases, the former in stone, and the latter in wood; these are described at pages 154, 165.

Such a stair is, for some reasons, very convenient, but can only be used when there is a considerable length of space available for the staircase compared with the height to be gained.

When this is not the case, the flights of steps are made to run in different directions, so that they are doubled up into a shorter space.

Flights running alternately in opposite directions are found to be a great relief in ascending a considerable height, and therefore a very long straight stair is objectionable.

A Dog-legged Stair[1] is so called from its being bent or crooked suddenly round in fancied resemblance to a dog's leg.

In this form of stair the alternate flights rise in opposite directions, as indicated by the arrows in Figs. 223, 226, and 247.

The ends of the steps composing each of these alternate flights are in the same plane with those of the other flight, so that there is no opening or well hole between them.

It is evident that—putting landings out of consideration—dog-legged stairs require only half the length of staircase that would be occupied by an equal number of steps of the same size arranged as a straight stair. On the other hand, the dog-legged stair requires twice the width of the straight stair.

Figs. 223-225 show a dog-legged stair in stone with a half-space landing. Figs. 246, 247 show a similar stair in wood.

[1] This term is generally used with reference to wooden stairs, but there is no distinct name for stone stairs of similar form. Stairs with rectangular well holes, such as those in Fig. 231, are sometimes called *dog-legged.*

In Fig. 226 there is no intermediate landing, the whole space being taken up with winders.

It will be noticed that all the winders converge to a point in the stair itself, so that they are very narrow near this end, and most inconvenient to ascend. This is a great drawback to the dog-legged form of stair, which, indeed, should never be used when winders are required, if there is room for a well hole between the flights.

A Geometrical Stair is one in which there is an opening or well hole between the backward and forward flights.

Such a stair requires of course a little more width, but only about the same length of space as a dog-legged stair.

The effect of the well hole is that the winders converge to a point between the flights, and have a certain amount of width even on the verge of the well hole. At a short distance inwards, where the person ascending places his foot, the winder is so broad as to afford a very convenient tread.

Figs. 228-230 show a geometrical stair in stone without intermediate landings, the space being occupied entirely by winders. Fig. 251 shows a similar stair constructed in wood.

Circular Stairs are composed of steps contained in a circular or polygonal staircase, towards the centre of which they all converge.

All the steps are necessarily winders.[1]

A CIRCULAR NEWEL STAIR is one in which the converging steps are supported by a newel at the centre of the staircase.

This newel may be either solid or hollow (see page 159).

A CIRCULAR GEOMETRICAL STAIR is in form the same as the last described, but that there is no newel. The steps converge as before, but rise round an open well hole instead of resting upon a newel (page 160).

STONE STAIRS.

Stone Stairs have an advantage over those of wood, inasmuch as they are much simpler in construction,[2] but the steps are heavy and require substantial walls for their support; moreover they become smooth under the friction of continued wear, and then are slippery and dangerous.

Stone Steps are generally solid blocks, and should be worked on

[1] Sc. *Wheeling steps.*

[2] Hanging stone steps are soon destroyed by fire; the part exposed to the heat expands, that imbedded in the wall does not, hence the steps snap off at the wall

the tread and rise, the former being for external steps slightly weathered, or the stone set with a slight inclination outwards.[1] In superior buildings the soffit also is worked, and the nosing may be moulded,[2] as shown in Fig. 219.

Steps and landings that cannot be got out in one stone must be of pieces jointed, joggled, and plugged together; in some cases it is necessary to support the landings on girders. Stone steps are sometimes formed with thin flags forming treads and risers, similar to those of wooden steps. Such steps require no further description. The following remarks refer to solid steps.

SQUARE STEPS are rectangular in section, as shown in Fig. 218.

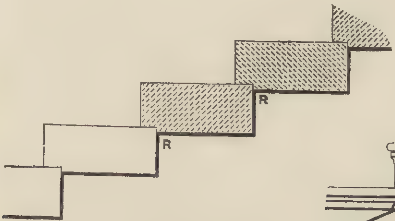


Fig. 218.

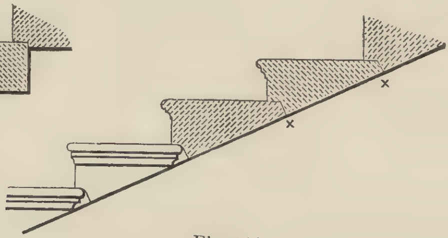


Fig. 219.

The hatched portion of these figures is in section, the remainder in elevation.

SPANDRIL[3] STEPS have the lower side cut away so as to form a raking soffit, as in Fig. 219; this is sometimes useful where headway is required under the stairs, it also makes the steps lighter, and is considered to have a better appearance.

FIXING STONE STEPS.—Stone steps may in some forms of staircase be supported at both ends by walls; in other cases one end only of each is built into the wall; these latter are called *hanging steps.*

The lowest step of a stair is sometimes sunk slightly into the ground to prevent it from sliding on its bed.

Steps supported at both ends are of most simple construction. The stone is rectangular in section, of a height exactly equal to the rise, and in width a little more than that of the tread (Fig. 221).

They are about 12 inches longer than the width of the stair, so that a length of 6 inches at each end is built into the adjacent walls.

When, however, these walls do not rise higher than the sides of the stair, the steps are of a length exactly equal to the width of the stair, and the ends are supported by walls built underneath them.

[1] Sc. this inclination is called the *kilt* of the stone. [2] Sc. *Bottled* or *Bottle-nosed.*
[3] Sometimes called Feather-edged steps.

Hanging Steps are each fixed at one end only; the outer end projects and is without support other than that afforded by the steps below it.

The fixed ends of hanging steps should be let into the wall about 9 inches, and very solidly and firmly built in.

As each step is supposed to depend to a certain extent on the support of the step below it, the joint between the two is so made that the pressure may be transmitted from one step to the other, and the parts in contact may be kept from slipping.

In square steps this is often done by cutting a rebate[1] (R R, Fig. 218) along the lower edge of the front of each step, into which fits the upper edge of the back of the step above, or a deeper rebate may be formed along the lower edge of the breast of each step, and the back-joint cut off at right angles to the soffit, as shown at Y Y in Fig. 220.

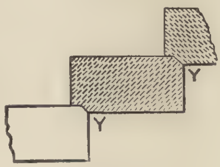


Fig. 220.

If the ends of the steps are securely built into the wall the steps cannot slide, and the rebate is of very little use; in fact, in the very best work it is sometimes omitted, unless the steps have a low rise, and would otherwise be too thin to bear the weight upon them, in which case their thickness can be increased by introducing the rebate.

A plain chamfered joint at right angles to the soffit, like that in Fig. 220 but without the rebate, is sometimes used.

Hanging steps may be built in as the wall is carried up; or, to avoid risk of damage to the steps, indents about 9 inches deep may be left in the walls, and the steps inserted afterwards: they should be pinned in with cement, and iron packing of hoop iron, pieces of old saws, etc.

Sometimes about 12 inches of the walling above and below the steps is built in cement.

Different Arrangements of Stone Stairs.[2]—STRAIGHT STAIRS.—Figs. 221, 222 show a straight stair composed of square steps supported at each end by being built into the side walls.

Fig. 222 is a horizontal sectional plan (looking downwards) through step No. 12.

The steps have 9 inches tread, and 7 inches rise, and between the flights (each consisting of 9 steps) is placed a landing.

[1] Sc. *Piend-Check.* [2] Figs. 221-237 are on a scale of $\frac{1}{8}$ inch = 1 foot.

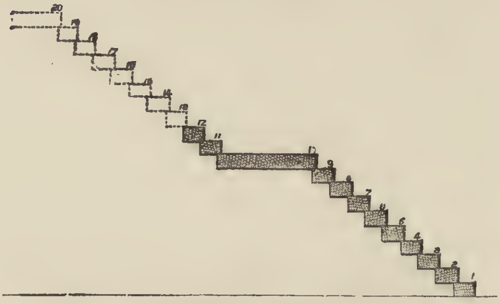


Fig. 221. *Section.*

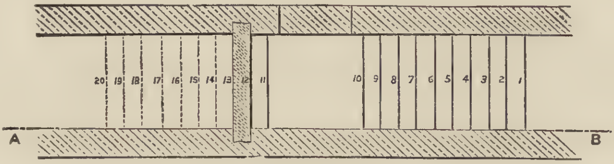


Fig. 222. *Plan.*

Dog-Legged Stairs in stone[1] are generally composed of hanging steps, the inner ends of which are firmly built into the walls

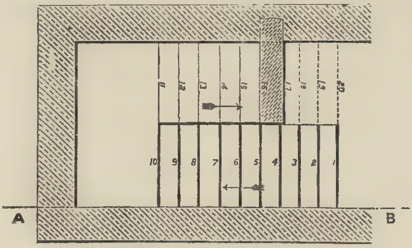


Fig. 223. *Plan.*

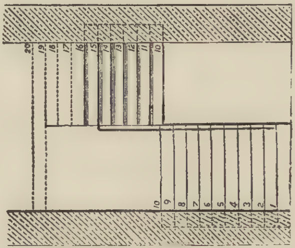
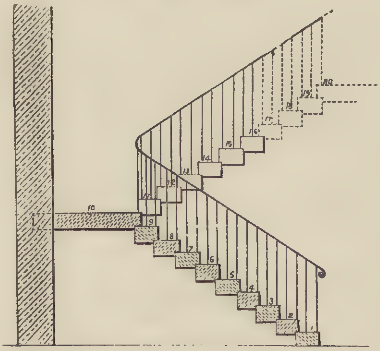


Fig. 225. *Elevation.*



Sectional Elevation on A B.
Fig. 224.

of the staircase, while the outer ends of one flight are in the same plane as those of the other flight.

Fig. 223 is a sectional plan (looking downwards) on the sixteenth step. Fig. 224 is a sectional elevation on the line A B, through the lower flight; and Fig. 225 is a front elevation of the stairs, showing the front of the lower flight and the back of the upper flight of steps

[1] See Note, page 151.

The stairs in Fig. 223 are shown with a half-space landing; but if the same height has to be gained when there is a smaller space available for the staircase, winders may be added so as to have only a quarter-space landing, similar to that in Fig. 249, or the whole space may be occupied by winders as in Fig. 226.

Winders would be necessary also in case a greater height had to be gained, without increasing the area of the staircase.

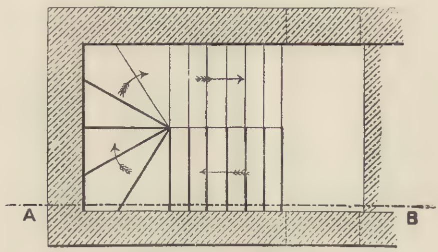


Fig. 226. *Plan.*

Sectional Elevation on A B.

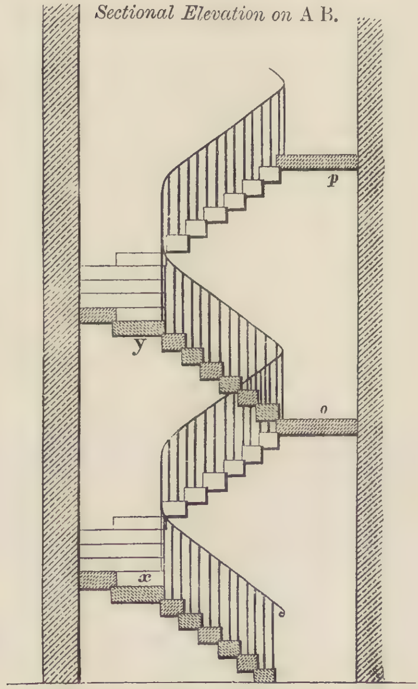


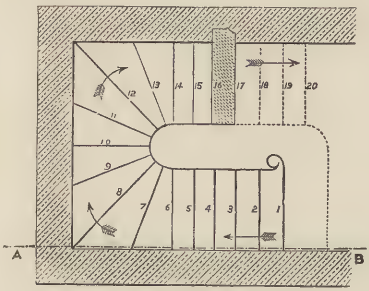
Fig. 227.

Figs. 226, 227 show a dog-legged stair with winders com-

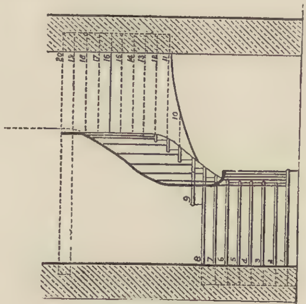
municating between three floors, These figures make clear the importance of having a sufficient headway between the flights running in the same direction (see *x y*), and also between the landings (see *o p*).

A Geometrical Stair in stone consists entirely of hanging steps, the outer ends of which are built into the walls of the staircase, while the inner ends abut upon the well hole of the stair, having no support but that derived from their successive connection, until they reach the floor.

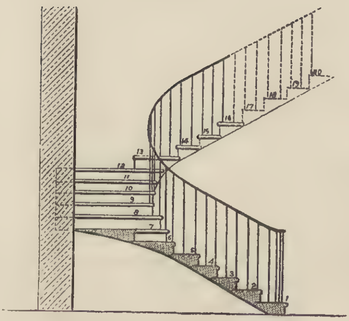
Figs. 228, 229, 230 give illustrations of a geometrical stair



Plan.
Fig. 228.



Elevation.
Fig. 230.



Sectional Elevation on A B.
Fig. 229.

in stone, with a narrow well hole, having a semicircular end. Fig. 228 is a sectional plan made through the sixteenth step looking downwards; Fig. 229 a vertical section through the lower flight, and elevation of the upper flight beyond; and Fig. 230 a front elevation of the staircase, showing the faces of the risers of steps of lower flight, and the backs of the steps of the upper flight.

The stair is constructed with spandril steps, and without a landing, except at the floors, the space being entirely filled with winders, the improved form of which, as compared with the triangular winders of the dog-legged stair, will be evident upon comparing Fig. 228 with Fig. 226.

Fig. 231 shows a geometrical stair adapted for a large and wide staircase.

This stair consists of three flights and two quarter-space landings, besides a large and wide landing (to which the stairs lead) on the level of the floor above.

The position and direction of the steps will be easily understood from the plan, without elevations, sections, or further explanation.

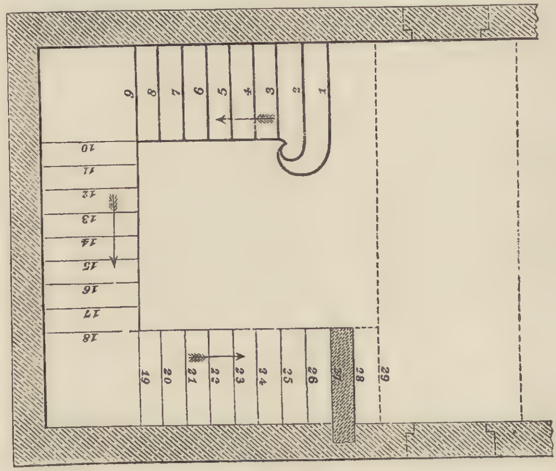


Fig. 231.

In some cases the inner corners of the quarter-space landings abutting on the well hole are cut off and made in plan of a quadrant shape, by which the curve of the handrail is improved at these points.

Such a stair takes up a great deal of room, and is only suitable for large and important buildings, where sufficient space can be afforded for the staircase.

In Fig. 231 a landing of the whole width of the staircase is shown at the level of the 29th step. Of course, if the arrangements required it, a quarter space landing at this point would be sufficient; from it would lead a flight parallel to steps 10 to 18, and running in the opposite direction.

Circular Stairs in stone may be composed either of steps supported at both ends, or of hanging steps converging toward a well hole; in either case, of course, all the steps are winders.

Circular Newel Stairs consist of square steps supported by the wall at one end, and at the other end by a "newel" or column of masonry, toward which they converge in the centre.

This newel may be either hollow or solid.

Fig. 232 shows an example of a circular stair with a hollow newel, consisting of a brick cylindrical shaft into which the inner

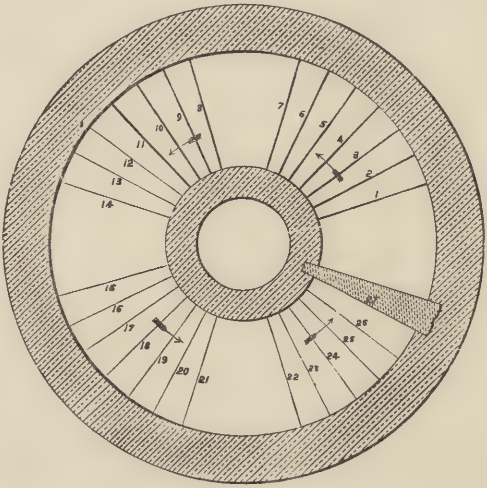
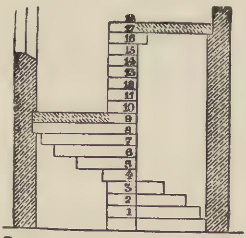


Fig. 232.

ends of the steps are pinned, the other ends being built into the outer wall of the staircase.

In some cases a thin wall is built round the centre newel, and also round the inside of the external wall, to support the ends of the steps, instead of building them in.

A very common construction, especially for circular staircases of small diameter such as those in turrets, is shown in Figs. 233, 234.



SECTION THROUGH *a, b.*

Fig. 233.

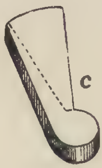
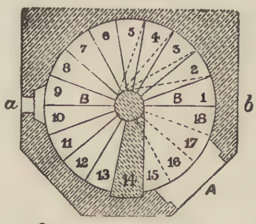


Fig. 235.



SECTIONAL PLAN.

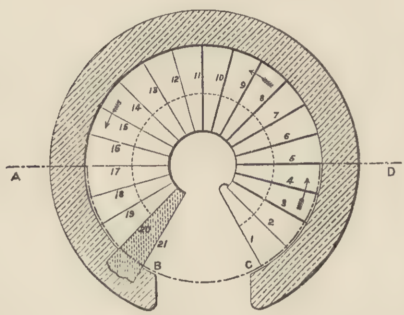
Fig. 234.

Each step is worked in the form shown in Fig. 235, with a

circular portion on the inner end, having a diameter equal to that of the intended newel.

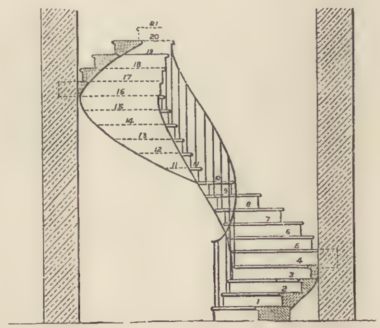
As the steps are built up the outer ends are secured in the wall of the staircase, while the circular portions at the inner extremity, being laid one upon another, give the step the required support, and form the newel of the stair.

Circular Geometrical Stairs consist entirely of hanging winders built into the outer wall of the staircase, and converging toward an open circular well hole down the centre.



Plan.

Fig. 236.



Sectional Elevation on A B C D.

Fig. 237.

Figs. 236, 237 show illustrations of such a stair. Fig. 236 being a sectional plan on No. 20 step, and Fig. 237 a sectional elevation.

The steps are of spandril section, except No. 1, which is necessarily square or it would have a very narrow base to rest upon.

WOODEN STAIRS.

Wooden Steps are lighter than those of stone, and do not require such strong supports. They are also more elastic, and do not become so smooth under wear as to be dangerous.

On the other hand, they are subject to decay, they may be more rapidly destroyed in case of a fire, and may thus cut off all exit from the upper floors.

Letters of reference in the figures connected with wooden stairs :—

Apron lining	*al*	Laths	*l*
Balusters	B	Outer strings	OS
Bearers	*b*	Pitching piece	P
Blocks	*bl*	Plaster	*pl*
Brackets	Br	Riser	*r*
Bridging joists of floor	*bj*	Rough brackets	*rb*
Cross bearers	*cb*	Rough strings	RS
Fillets	*fi*	Soffit joists	*sj*
Furrings	*f*	Tread	*t*
Glued block	*gb*	Trimmer	T
Handrail	HR	Trimming joists of floor	TJ
Joists of landing	*j*	Wall strings	WS

N.B.—The handrails are shown in the elevations in order to make the direction of the steps more plainly evident; but they are omitted in the plans for fear of rendering them obscure. The skirtings are also omitted from the plans. The plaster of the wall is also omitted from both plans and sections of the figures on a small scale.

Parts of Wooden Stairs.—STRINGS[1] are thick boards or pieces of timber placed at an inclination to support the steps of a wooden stair.

Cut Strings.—Wooden stairs of the commonest description are thus constructed.[2]

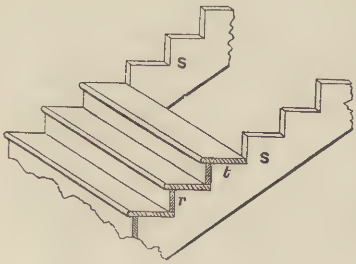


Fig. 238.

Two "*strings*," SS, are fixed at the slope determined upon for the stairs; in these rectangular notches are cut, each equal in depth to the rise, and in width nearly equal to the tread of a step: upon these boards are nailed, forming the treads, *t*, and risers, *r*.

Cut and Mitred Strings.—In stairs of a better description the

[1] Sc. *Stringers.*

[2] Stairs of this construction are never used in ordinary house-building.

outer strings are cut as above described; but the ends of the risers, instead of coming right through and showing on the outer surface of the string, are mitred against the vertical part of the notch in the string, as shown at *aa* in Fig. 240, the other end of the step being, as before, housed into a groove formed in the wall string.

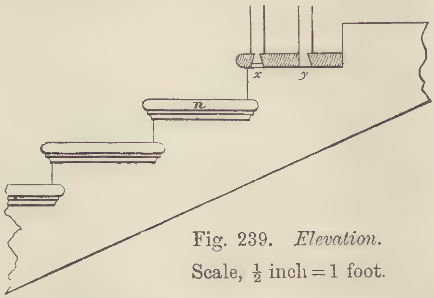


Fig. 239. *Elevation.* Scale, ½ inch = 1 foot.

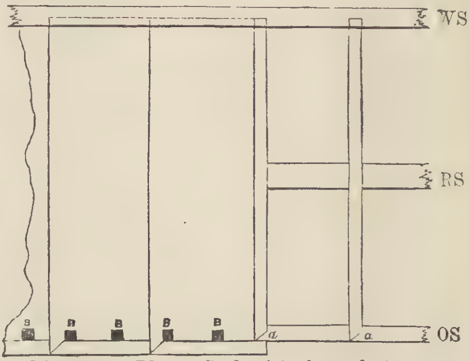


Fig. 240. *Plan.* Scale, ½ inch = 1 foot.

The outer extremity of the tread is also cut and mitred, as shown in Fig. 240, to receive a return moulding, forming the nosing of the end of the step.

BB show the mortises for the balusters, which should be dovetailed into the treads;[1] the dovetails may be formed as at *x* or as at *y*, Fig. 239

Housed Strings.—In many staircases the strings, instead of being notched out to receive the steps, are left with their upper surfaces parallel to the lower, and grooves are cut into their inner sides to receive the ends of the treads and risers; these grooves are called "*housings,*" and the steps are said to be "*housed*" into the strings.

Fig. 242 is an elevation of the inner side of a housed string, showing the sinkings or housings formed to receive the steps.

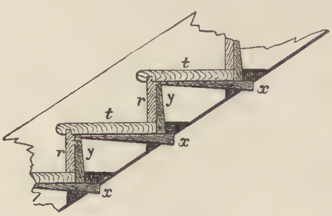


Fig. 241.

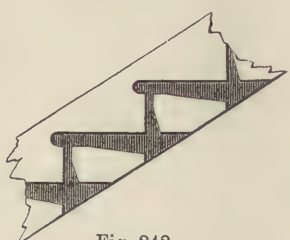


Fig. 242.

Scale, ½ inch = 1 foot.

Fig. 241 is a sectional elevation through the steps, showing the

[1] In speculative work the ends of balusters are simply skew-nailed to the treads or let into them without dovetailing, so that the balusters simply hang from the handrail.

treads, t, and the risers, r, in position. These are secured by means of wedges, x y, which should be well covered with glue before insertion.

The treads are sometimes formed with two tenons at each end, which fit into mortises cut through the string.

Open Strings are those, such as the cut strings, or cut and mitred strings, described above, which are cut so as to show the outline of the steps.

Close Strings have their upper and lower surfaces parallel, the steps being housed into them as above described (see Fig. 241).

A Wreathed String is one formed in a continuous sweep round the well hole of a geometrical stair.

The Wall String is the string up against the wall, and plugged to it. WS, Fig. 248.

The Outer String is the string at the end of the steps farthest from the wall. OS, Fig. 248.

Rough Strings.—With stout treads and risers the two strings above mentioned are sufficient for stairs of 3 or 4 feet in width.

For wider stairs, however, the steps require additional support, and this is afforded by means of one or more "rough strings," or "*carriages*," fixed in the interval between the wall string and outer string, already described.

Two rough strings are shown in Fig. 245, for the sake of illustration, but one only would be necessary in so narrow a staircase; one rough string is shown in Fig. 247.

The scantling for rough strings may be about the same as those for bridging floor-joists of the same length (see p. 141, Part I.)

The rough strings sometimes have small notches on their upper surfaces to receive the back edge of the tread, and their ends are attached to trimming joists TJ (see Figs. 244, etc.), or into pitching pieces P (Fig. 251), or trimmers T (Fig. 245), where trimming joists are not available.

Wooden Steps are formed of boards, as shown in Fig. 243.

The risers are united to the treads by joints, which may be grooved and tongued, as in steps 5, 6—feathered as in step 4—or rebated, as No. 3; in every case the joint is glued. The riser often has only its upper end tongued, the lower butting upon the tread below. This is not so good a construction as that shown at 3. A common practice is to house the lower edge of the riser into the tread below, as at x. The tread is sometimes tongued into the riser, but that is not a good construction.

The joint between the tread and riser is strengthened by small

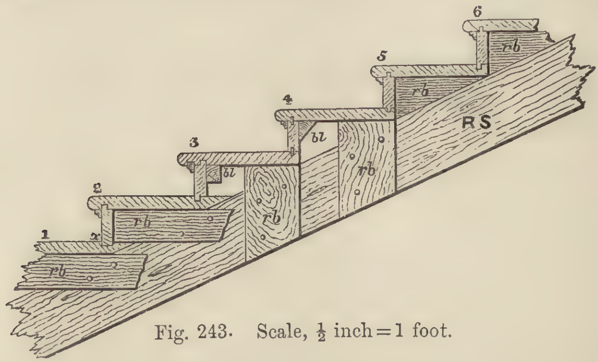


Fig. 243. Scale, $\frac{1}{2}$ inch = 1 foot.

blocks, *bl*, glued into the inner angle, as shown in steps 3 and 4; these may be either rectangular or triangular in section.

The inner ends of the treads rest upon the rough strings, RS (if any), and they are frequently further supported by rough brackets, *rb*, attached to the rough strings or carriages.

These brackets may be pieces nailed alongside the string, as in steps 1, 2, 3, 4, or triangular pieces fixed to its upper surface, as in 5 and 6.

Occasionally vertical brackets are made of a width equal to that of the tread of the step, as at *xy* in Fig. 246.

In some cases a board is notched out like a cut string and nailed alongside the rough string, to answer instead of the rough brackets (see Fig. 250).

The treads project over the risers and are finished with a rounded or a moulded nosing, the projection of the nosing being generally equal to the thickness of the tread. When a moulded nosing is adopted with an open string, the moulding is returned at the end of the step, being mitred at the angle, as shown at Fig. 240.

The mouldings are generally planted on under the rounded nosing of the tread.

The treads should be of oak or other hard wood, and may be $1\frac{1}{8}$ inch thick for steps 4 feet long—the thickness being increased by $\frac{1}{8}$ inch for every 6 inches added to the length of the step.

In very common stairs the risers are sometimes dispensed with.

In some cases, especially in geometrical stairs of a high class

the upper edges of the risers are dovetailed to the treads, and the back of the treads screwed up to the lower edge of the risers.

Different Forms of Wooden Stairs.—STRAIGHT STAIRS.—In very narrow stairs of ordinary construction, with a wall on one side only, the following is the arrangement usually adopted.

Two grooved strings, OS and WS, Fig. 245, are placed at the required slope, and at a distance apart equal to the length of the steps.

The wall string, WS, is fixed by being plugged to the wall. The ends of the treads and risers are keyed into the housings or grooves worked in the inner and outer strings.

The upper and lower ends of these strings are framed into newel posts, and so are the outer ends of the first and last risers of each flight. When the flight of steps extends uninterruptedly from the lower to the upper floor, these newels are attached to trimming-joists, TJ, provided in the floors to receive them.

When the flight is broken by a landing, additional newel posts are provided on each side of the landing, and extending the full depth between the floors, as in Fig. 244.

To these are secured the trimmers, T, fixed and wedged into the wall, and projecting from it to carry the landing.

As already mentioned, the two strings are sufficient for stairs with stout treads and risers up to a width of 3 or 4 feet.[1]

For wider stairs, however, additional support to the steps is necessary, and this is afforded by one or more rough strings (RS, Fig. 245) or carriages placed in the interval between the strings already described.

The ends of these rough strings are framed or housed into the trimming-joists provided to receive them in the floors, between which the stairs extend.

When there is a landing the upper ends of the rough strings are fixed to the special trimmers which carry the landing.

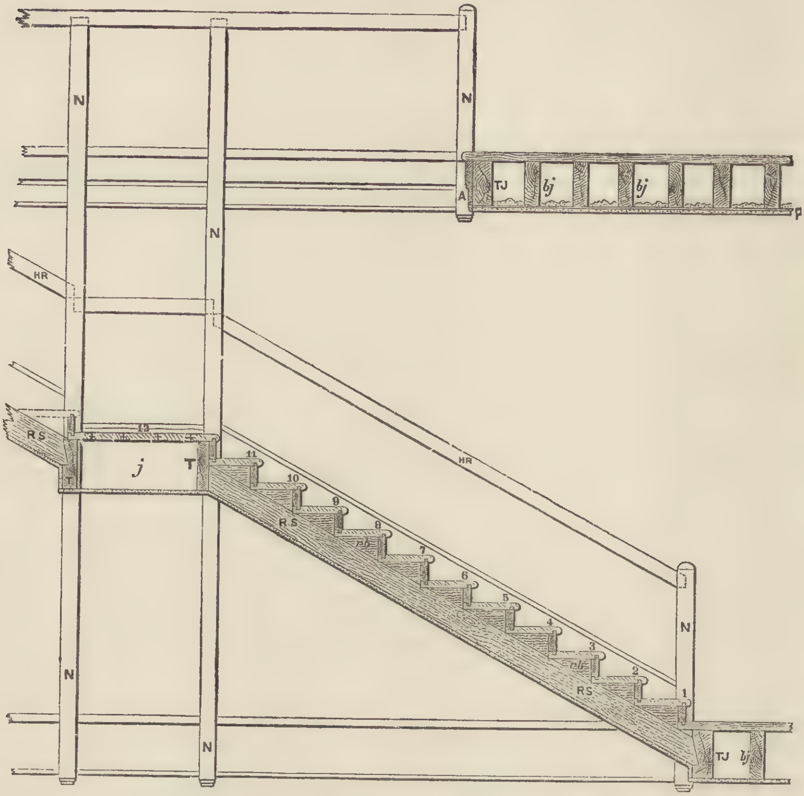
The treads are further supported by rough brackets *rb*, Fig. 244, secured to the rough strings.

The landing itself is formed like a floor, of boards laid upon joists framed in between the trimmers just mentioned.

When there is a wall on each side of the steps, of course the newels are not required.

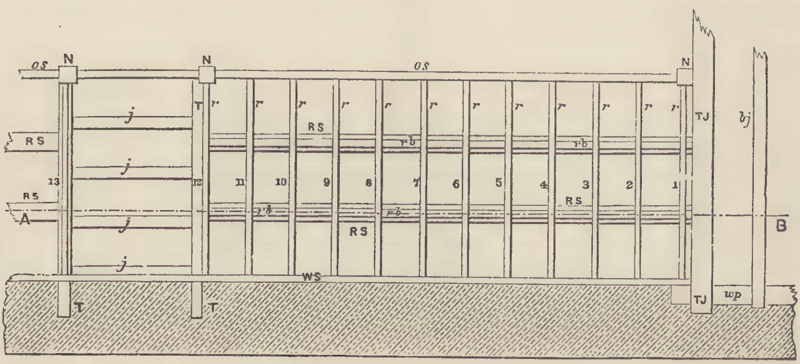
When the floor is continued under the lowest flight of a stair, the space between the soffit of the stairs and the floor is called the *spandril*.

[1] When the outer string is a *cut-string* it is never desirable to omit the carriage, however narrow the stair may be, as it would cause creaking, if not positive weakness. Even when both strings are close a carriage is an advantage.



Section on A B.

Fig. 244.



Plan (with treads and boarding removed).

Fig. 245.

Figs. 221, 222. Straight Stairs. Scale, ¼ inch = 1 foot.

This space is often utilised as a cupboard by enclosing it with a panelled front (containing a door, and sometimes a window), known as the *spandril framing.*

Dog-legged Stairs.—Fig. 247 is the plan of a dog-legged stair with a half-space landing. The treads of the steps in the lower flight are omitted, so as to show the strings and risers. A portion of the steps of the upper flight is broken away in order to expose to view the construction of the flight below.

In this stair the wall string, WS, and outer string board, OS, are constructed as before, with intermediate rough strings if necessary.

The outer strings are tenoned into the newels, and so are the first and last risers of the flight.

The outer string of the upper flight and that of the lower flight are in the same vertical plane, so that if the plan of the upper flight were complete the outer string of the upper flight would overlap and hide the outer string of the lower flight.

In the same way, if the number of steps in each flight were the same, the newel, N_3, of the upper flight would in plan exactly cover the newel, N, of the lower flight, being immediately over it.

The handrail in the plan is omitted as before.

Fig. 246 gives the elevation of the upper flight, and the section of the lower flight of the stairs shown in Fig. 247; but no portion of the elevation is broken away, and the treads of the lower flight are shown in section, though omitted from the plan.

The newels are fixed to trimming joists TJ, provided in the floors, and to trimmers T across the staircase at the landing.

The rough strings, RS, are framed in between these trimmers, and rough brackets, *rb rb*, are nailed alongside of them to support the steps.

The tread of the top step is frequently united to the boarding of the landing by a rebated joint. This is advisable if the space below the steps, known as the spandril, is to be made use of as a cupboard. In such a case the landing and the parts of all the steps should be put together with tongued joints, so that dust may be prevented from getting through them. Such joints are often used in superior work even when there is no cupboard below.[1]

Newel Stairs is another name given to dog-legged stairs, because the newels form a conspicuous part of the structure.

[1] It is more cleanly to lath and plaster soffits of stairs even in cupboards.

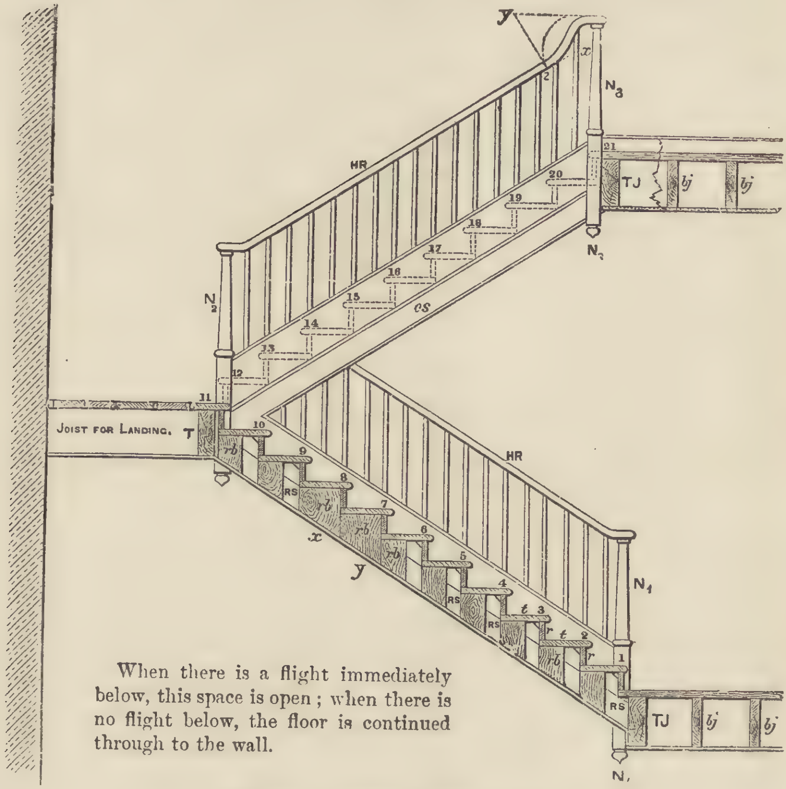
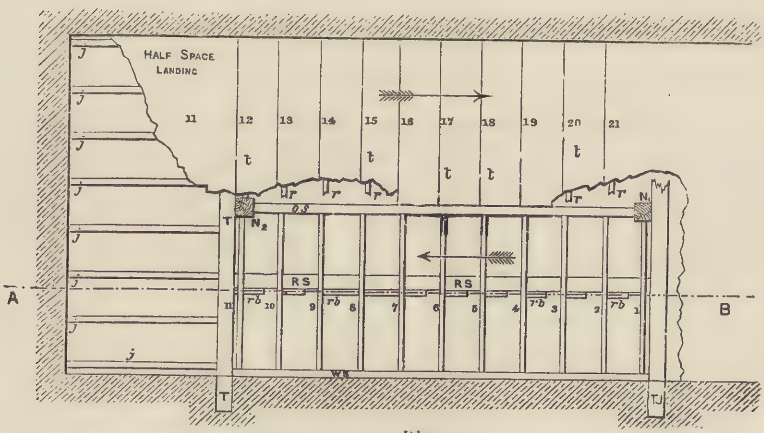


Fig. 246. ***Sectional Elevation on*** A B.

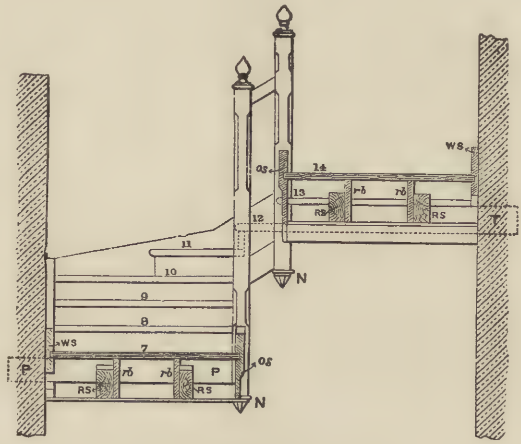


Plan.

Fig. 247.

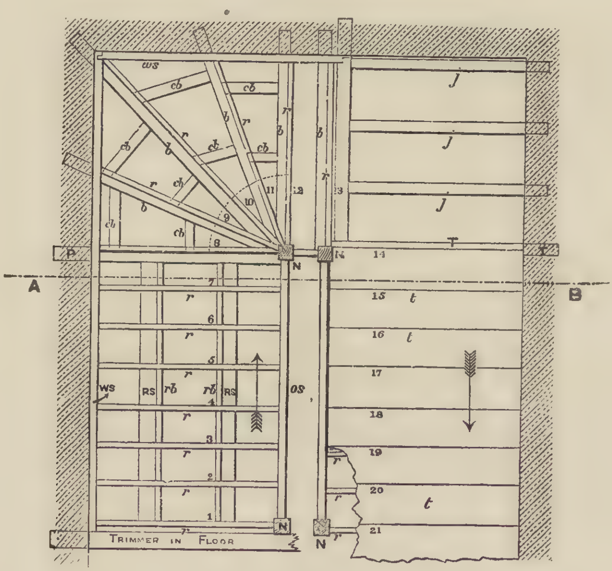
Figs. 246, 247. Dog-Legged Stairs. Scale, ¼ inch = 1 foot.

Open Newel Stairs have newels arranged round an opening or well hole in the centre between the flights of steps.



Sectional Elevation on A B.

Fig. 248.



Plan.

Fig. 249.

Figs. 248, 249. Open Newel Stairs. Scale ¼ inch = 1 foot.

Fig. 249 shows the plan of such a stair, with a quarter-space landing.

The boarding of the landing and the treads of the lower flight are omitted on plan, in order to show the construction below.

Fig. 248 is a sectional elevation on A B. The treads of the lower flight are shown in elevation though omitted from plan.

The construction of the straight portion of the stairs is similar to what has already been described. The winding steps are constructed as follows:—

Bearers, *bb*, carrying the risers, *rr*, are framed into the newels, their outer ends resting in the wall of the staircase. Between them are fixed cross bearers, *cb*. These would not be necessary in a narrow staircase, but are inserted in Fig. 249 for the sake of illustration.

In this example four winders are introduced to show the defects of such an arrangement as pointed out at page 178.

In Figs. 249, 251 the skirting is omitted in that portion of the plan where the treads are shown.

Geometrical Stairs have no newel posts. The flights are arranged around a well hole in the centre—sometimes called an "*open newel*"—and each step is secured by having one end housed into the wall string, the other end resting upon the outer string, but partly deriving support from the step below it.

The handrail is uninterrupted in its course from top to bottom.

The treads for geometrical stairs should be substantial.

The string may be greatly strengthened by a flat iron bar screwed to its under side.

Figs. 250, 251 give a plan and sectional elevation of a geometrical stair with winders.

The portion of the staircase shown in Fig. 251 consists of six fliers, then eight winders, then seven more fliers, making 22 steps, leading to a half-space landing on the floor above; from this the stairs again rise, commencing with the step marked 23, the remainder being broken off to show the first flight.

The treads of the lower flight and winders are also omitted, in order to show the supports below.

The steps are formed in the way described at page 163, with (in this case) feather-tongued joints between the treads and risers.

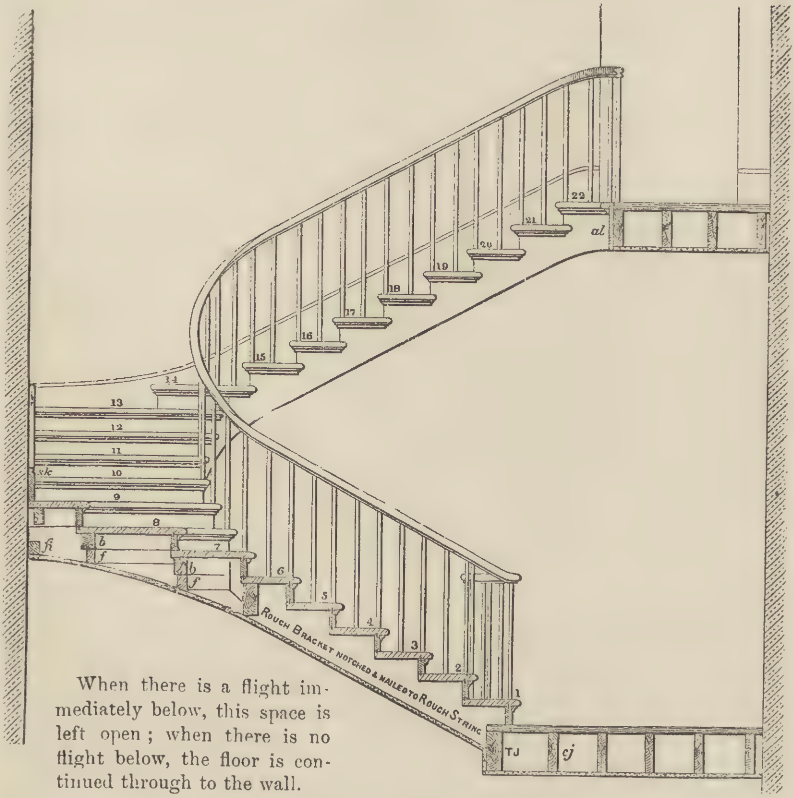


Fig. 250. *Sectional Elevation on* A B C D

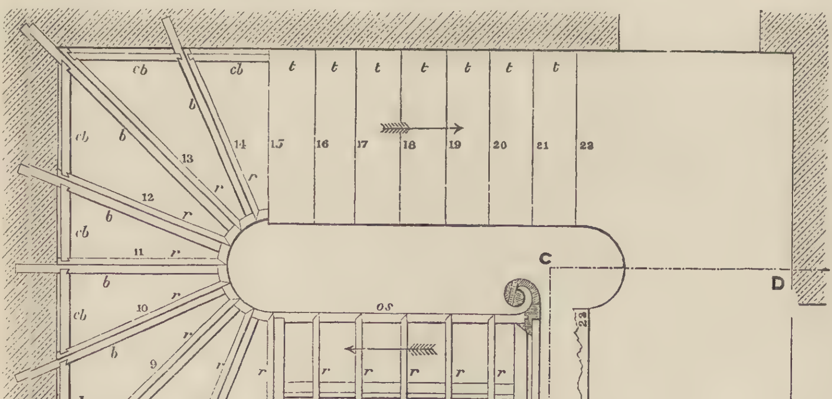


Fig. 251. *Plan.*

Figs. 250, 251. Geometrical Stairs. Scale, $\frac{1}{4}$ inch = 1 foot.

The handrail has, as before, been omitted from the plan for the sake of clearness.

The treads and risers are housed into the wall string, the outer ends resting upon a cut and mitred string, and intermediate support is afforded by a rough string, to the side of which is nailed a rough notched bracket, cut to fit the under side of the steps, and to serve instead of brackets.

The strings themselves are framed in between the trimming joists provided in the floors, and *pitching pieces*, P, projecting from the wall at the level of the first and last winders; one of these latter is shown at P, but the other is covered by the fifteenth step.

The trimming joist just below No. 1 step extends of course right across the staircase—but it is in the plan (Fig. 251) supposed to be broken off just under the outer string in order to avoid confusing the plan of the curtail step.

The winders are supported throughout their length by bearers, *bb*, the inner ends of which are built and wedged into the wall of the staircase, the outer ends being tenoned into the circular or wreathed portion of the outer string.

The risers are nailed to these bearers, and the widest ends of the steps are supported by cross bearers dovetailed in between the risers and the longitudinal bearers above mentioned.

The lowest step of this staircase is formed with a curtailed end which, when the tread is on, in form somewhat resembles that shown in the stone staircase, Fig. 231.

In this illustration, however, the tread of the curtail step has been omitted in order to show the construction of the riser below, which is built up in a curved form, terminating in a circular block, which forms the base to support the last baluster or newel.

The inner side of the staircase is finished and embellished by a skirting notched on the under side to fit the steps, and secured to narrow grounds plugged to the wall.

In some cases two cross bearers are provided for each winder, one being framed in between the longitudinal bearers in the centre as well as that at the wide end, as in Fig. 249.

If very thick treads are used, the bearers and rough strings may be omitted altogether, the steps being wedged into the wall and projecting without further support till they reach the outer string.

Fig. 252 is a portion of a stair similar to that in Fig. 250, but with different descriptions of joints between the treads and

risers, enlarged in order to show the plaster and other details,

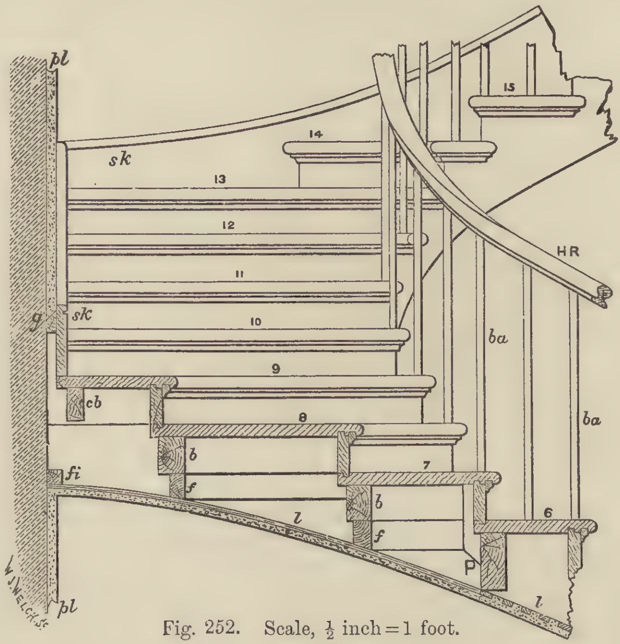


Fig. 252. Scale, ½ inch = 1 foot.

which could not be made clear upon a very small scale.

Solid steps, like those of stone, are sometimes formed in wood for geometrical staircases, and make strong but expensive work.

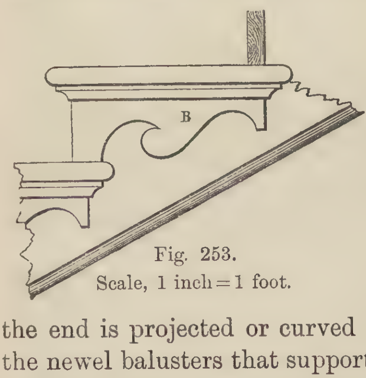


Fig. 253.
Scale, 1 inch = 1 foot.

A Bracketed Stair is one which has ornamental brackets, B, (Fig. 253) fixed on to the end of each step above the outer string and mitred to the outer end of the riser.

They are put on merely for the sake of appearance, and play no part in supporting the steps.

A Curtail Step is one of which the end is projected or curved (as shown in Fig. 228) to receive the newel balusters that support the scroll terminating the handrail.

It is not unusual, especially in stone stairs, to make the last two steps of curtail form, as shown in Fig. 231; in some cases three or more steps are curtailed.

When the end of the step is circular it is called a *round-ended* step.

Carriages is a general name applied to the rough timbers, such as strings, etc., used for supporting a stair.

To avoid framing in bearers for every winding step, two or three carriages are sometimes fixed, as shown in Fig. 256, across the staircase, parallel to the fliers; to these carriages are attached rough brackets for support of the winders, wherever the latter happen to cross them.

HANDRAILING.—The height of the handrail should not be uniform throughout, but varied slightly within the limits of a few inches, so as to secure a graceful line at the changes of inclination.

The handrail should be higher on the landing, where the person using it is erect, than on the steps, where he will be inclining either forward or backward, according as he is ascending or descending the stairs.

[The height from the treads (at the nosings) to the upper surface of the handrail should be 2 feet 7½ inches; to this there should be added at the landings the height of half a riser.—*Newland.*]

For winding stairs regard should be had, in adjusting the height of the rail, to the position of the person using it—who may be thrown farther from it, not only by the narrowness of the treads, but by the oblique position of the risers.

The handrail should be raised over winders, especially those of a steep pitch.

Nicholson recommends that the upper surface of the handrail should have a diameter of 2¼ inches; but the sizes vary greatly—3 or 3½ inches by 2 or 2½ deep being common dimensions, while, for very important staircases, the handrail may be 6 × 4 inches, or even larger.

The different sections of handrails are distinguished by peculiar names, according to their shape, such as "Mopstick handrail," a nearly circular form; "Toad's back," which has a flattish, curved upper surface, etc. etc.

The handrail may be secured to the balusters by means of a flat bar of wrought-iron about ¼-inch thick, and in width equal to that of the top of the baluster.

This bar, C in Figs. 254, 255, is called a "*core*," and it is screwed down upon the heads of the balusters, and up to the under side of the handrail, as shown in the figure, which represents a piece of the horizontal portion of the handrail to a landing.

Fig. 254.

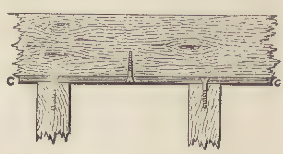


Fig. 255.
Scale, 2 inches = 1 foot.

The balusters supporting the inclined handrail over the steps have their tops splayed to fit the lower surface of the rail. In common work the balusters are nailed to the handrail direct, without the intervention of a core.

A Wreathed Handrail is one which ascends in a continuous curve round a circular well hole, as in Fig. 237.

A Ramp is the sudden rise, concave in form, made by a handrail where it is stopped, as against the newel in Fig. 246.

A Knee is the convex part of the sudden rise in a handrail, as in Fig. 246.

A Swan Neck is a ramp and knee combined, being concave in one part and convex in another; see Fig. 246.

The method of setting out the handrailing for different forms of stairs is quite a science in itself, and is fully treated upon by Mr. Mayer in Newland's *Carpenter's and Joiner's Assistant,* whence many of the above hints have been taken, and to which the student must be referred if he should wish to pursue the subject farther.

BALUSTERS are intended to support the handrail and to prevent any one from falling over the ends of the steps.

They should not be more than about 5 inches apart.

They are sometimes vertical wooden bars, square, turned, or carved, according to the class of work.

An iron baluster of the same pattern as the wooden ones should be introduced at intervals (generally about 1 in every 10) to strengthen the whole.

Iron balusters are frequently used throughout.

Wooden balusters should be dovetailed into the treads of the steps, and secured to the handrail as above described.

The balusters are sometimes fixed to the outer string, being bent or kneed so as to clear the ends of the steps, in order to give as much width as possible to the stairs.[1]

Generally there are two balusters fixed on the end of each step—one flush, or as nearly as possible flush, with the face of the riser, the other midway between the risers.

On each of the narrow ends of winders one baluster only is required.

General Remarks on planning Stairs.—Before planning or laying out a stair, the following particulars are required to be known, and are generally determined by circumstances.

1. The height of the stairs, that is the vertical distance between the surfaces of the floors to be connected by the stair.

[1] This is the French system, and involves the use of iron balusters, or iron balusters and iron brackets, or of iron brackets alone.

2. The position of the first and last risers. These must be conveniently arranged in connection with the approaches, doorways, etc., leading to and from the stairs.

3. The width and length of the staircase available.

4. The position and dimensions of doors, windows, etc., surrounding the staircase, and clear of which the steps must be kept.

These particulars being known, the description of stairs to be adopted can be determined upon, the choice being further influenced by the class of building in which the stairs are to be erected.

Thus, in small common houses or cottages with a very narrow space for the staircase, a straight stair may be necessary. In a slightly better class of house there may be just sufficient width for alternating flights, and a dog-legged stair will be suitable. In buildings on a larger scale, with spacious staircases, a geometrical or open newel stair may be constructed, the well hole increasing in width with that of the staircase.

Circular geometrical stairs with solid or open newels are required in towers, and stairs such as those in Fig. 234 are necessarily made use of in a turret.

The description of stair having been decided upon, no general rule can be laid down for the arrangement of the steps. Some ingenuity and contrivance will be required in order to proportion and arrange them so as to fulfil all the conditions of a good stair fitted to the peculiarities of the position.

Such a stair will consist of flights running alternately in opposite directions, and each containing not more than 10 or 12 steps. All sudden alterations in the length of flights, especially single steps introduced here and there, should be avoided. The landings between the flights should be of a length and width at least equal to the length of the steps. Winders should be avoided as much as possible, and the steps should have the rise and tread carefully proportioned to one another, as directed at page 150. Care must also be taken that when one flight passes under another, or below a landing, there should be plenty of headway; and also that the steps are clear of all doors and windows in the staircase. The stairs should be well lighted throughout their length, more especially at the approaches.

The light may be furnished by windows in the sides of the staircase above the landings, or by a lantern at the top, the latter giving the best and most equally diffused light.

Laying out the plan of Stairs.—Straight Stairs.—The planning of a straight stair is a very simple matter.

The height of the storey being known, a convenient height for the risers, appropriate to the class of staircase (see page 150), is assumed *pro tem.*

The total height to be gained, divided by this dimension, gives the number of risers, the number of treads will be one less (see page 157); and the proper width for each tread (in proportion to the height of the riser) will be found in the table, page 150. If there is room in the staircase for the required number of treads of this width, with the necessary landings, well and good; if not, a steeper rise must be assumed, requiring narrower treads and fewer of them, for which there will be room.

Thus, in the staircase, Figs. 221, 222, the height to be gained is 11 feet 8 inches: assume 7 inches for height of risers, $\frac{140 \text{ inches}}{7 \text{ inches}} = \text{number of risers} = 20$. The width of the tread proportionate to such a riser (see page 150) is 9 inches, the number of treads 19. The total length of staircase required for the treads will be 19×9 inches $= 14$ feet 3 inches; thus, without a landing, a staircase 14 feet 3 inches long will be sufficient, but with a landing 4 feet wide, substituted for one of the treads (14 feet 3 inches + 4 feet − 9 inches) = 17 feet 6 inches, will be required for the length of the staircase.

The risers must be equal throughout the stairs, none higher or lower than the rest should be introduced to make up an awkward dimension in the vertical distance. Thus, in the case just given, if the height to be gained had been 11 feet 6 inches, the number of 7-inch risers required would have been $\frac{138}{7} = 19\frac{5}{7}$: it would not do to have nineteen 7-inch risers, and one 5-inch riser; but 20 risers would be used, each $\frac{138}{20} = 6\frac{9}{10}$ inches in height, thus equally dividing the vertical distance to be gained.

Laying out Dog-legged Stair.—The number of steps to be introduced is ascertained in the same way as for a straight stair. Thus, in the Fig. 224, a height of 10 feet 10 inches has to be gained, there are 20 risers each $6\frac{1}{2}$ inches high, and the steps have a proportional breadth of 10 inches. The stair is in two flights, each containing 10 steps, and separated by a half-space landing.

The length of staircase required for the width of treads is 9×10 inches $= 7$ feet 6 inches; and for the landing (equal to width of stairs) 3 feet 6 inches, or 11 feet altogether.

When, however, the area of the staircase is more limited in proportion to the height to be gained, the landing must be made smaller or done away with, and winders introduced; the steps also may be made steeper, so that fewer of them are required, and they take up less room, as the proportionate tread for each is less.

Suppose, for example, that the staircase has a length of only 8 feet, and that the height to be gained between two floors is rather more than before, viz. 11 feet 1 inch (see Fig. 227).

In this case the landing shown in Fig. 223 has to be sacrificed and winders introduced, while the steps are made steeper, so that 19 only are required; the height of each of these is $\frac{133}{19}$ inches = 7 inches,[1] the corresponding tread being 9 inches, the total length taken up by the steps being 6×9 inches = 4 feet 6 inches for the fliers—in addition to 3 feet 6 inches (the space containing winders)—altogether 8 feet.

Winders.—In laying out winders it should be remembered that when a person on the stairs is using the handrail he places his foot on the steps about 18 inches in from the balusters; each winder should, therefore, at a distance of 18 inches in from the handrail, have a width equal to that of the treads of the fliers,[2] otherwise (the fliers being properly proportioned) the winders will at this point be too narrow in proportion to their height.

This cannot always be accomplished in dog-legged stairs; for instance, if it were absolutely necessary to introduce three winders into a quarter-space of the landing of the stair shown in Fig. 223, these could only have a width of $9\frac{3}{7}$ inches at 18 inches in from the handrail, whereas the fliers have a width of 10 inches.

For a similar reason *four* winders should be avoided as much as possible in dog-legged stairs. It will be seen in Fig. 249 that the width of treads at 18 inches from the newel can never be more than 7 inches. Thus the treads of the winders must be narrower than those of the fliers, and therefore inconvenient.

Four winders are, however, very frequently introduced as shown, for they are often absolutely necessary in order to gain the height required within the space available.

[1] If the height to be gained were the same as in Fig. 224, viz. 10 feet 10 inches, the rise for the steps would be $\frac{130}{19} = 6\frac{16}{19}$ inches.

[2] If the staircase be narrower than 3 feet, the width of treads should, of course, be laid off along the centre of the winders. It is sometimes considered better to have three or even five winders than four; because when there are four there is a riser of needless length running into the angle of the staircase (see Fig. 249).

As it is difficult to follow these rules under all circumstances they are often infringed, and in common staircases it is considered quite sufficient if there is a proper width of tread in the centre of the length of the winders.

"Balanced" or "Dancing" Steps.—In consequence of the inner ends of winders having such narrow treads, while their height is the same as that of the other steps, the inclination of the line of nosings of the winders is much steeper than that of the fliers—which gives a sudden and ungraceful change to the inclination of the handrail above them.

To avoid this, and in order to gain some additional width at the inner ends of the winders, they are in some cases made to "dance,"—that is, they are drawn so as not to converge to the same point, but so that each is directed upon a different point—found in a manner too intricate to be entered upon in this work.

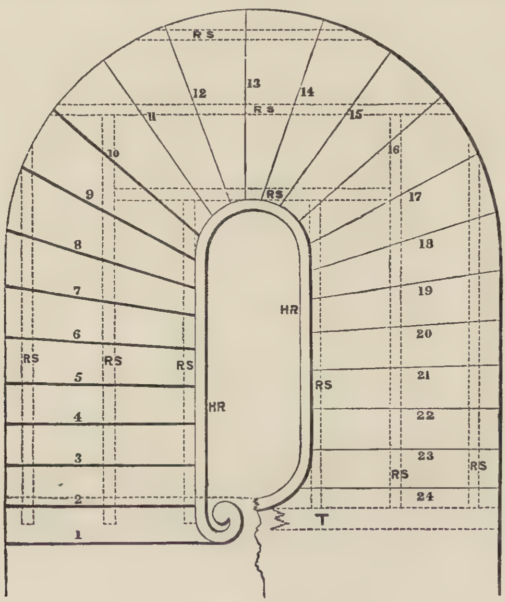


Fig. 256. Scale, $\frac{1}{4}$ inch = 1 foot.

In Fig. 256 the first four and the last four steps are parallel —but the remainder are "balanced" or "dance," as above described.

Geometrical Stairs.—In laying out geometrical stairs the steps are arranged on the same principles as those above described.

The well hole in the centre is first laid down and the steps arranged round it.

In circular stairs with an open well hole, as in Fig. 236, the handrail being on the inside, the width of tread proportioned to the rise of steps should be set off along the dotted line, 18 inches in from the handrail, for the reasons above mentioned.

In stairs with a newel, such as that in Fig. 232, when the handrail, if any, might be on the outside, it will be sufficient if the steps have the proper width of tread in the centre of their length.

When laying out stairs practically on the building itself, the height to be gained is carefully marked out upon a "*story rod*," on which are marked divisions corresponding in number and height to the risers: a similar rod is marked so as to show the treads; and from these rods the steps should be carefully marked upon the walls of the staircase.

A rod should also be prepared having marked upon it the exact width of the staircase, the length of steps, the position and size of newels, and also the size of the wall and outer strings, showing the thickness and the depth of the housings.

CHAPTER VIII.

FIREPROOF FLOORS.

General Remarks.—Fireproof floors are of great service in preventing flames from spreading throughout a building.

A great many different systems of fireproof construction have been proposed during the last few years; and before describing the most important of these it will be desirable to state what characteristics should be looked for in a good fireproof floor.

Characteristics of good Fireproof Floors.

In estimating the efficiency of any system of fireproof flooring the undermentioned points should be attended to.

A, PROTECTION OF IRONWORK.

The structure of a fireproof floor is generally dependent upon the ironwork; if that is destroyed or gives way the floor must follow. Iron girders and columns may be protected by terra-cotta blocks, see Figs. 259, 278, etc., or by concrete, see Figs. 274, etc.

B, RESISTANCE TO FIRE OF THE MATERIAL COMPOSING THE FLOOR.

Brickwork and hard burnt clay are the best fire-resisting materials.

Mild steel, if not protected by a non-conductor of heat, will warp and twist under the action of fire and destroy the structure.

Cast-iron cracks and gives way suddenly, especially when it is heated and then drenched, as it is likely to be during a fire. In the Chicago fire the ends of cast-iron columns were actually melted off.

Timber in large scantlings will resist the action of fire for a long time if the flames cannot get round its sides or ends. After it becomes charred to a certain depth the charcoal formed on its surface, being a non-conductor, protects it.[1]

[1] Lawford, *Transactions*, Society of Engineers, 1889, p. 43.

Wooden floors will resist a considerable action of fire if well imbedded in mortar, which, however, leads to their premature decay.

Wood may be rendered partially fireproof by being coated with cyanite, Asbestos paints, or other substances mentioned in Part III.

Concrete is generally a good fire-resisting substance, but this depends to some extent upon the materials of which it is composed.

Gypsum (sulphate of lime) is weaker than Portland cement, but resists fire better, as it does not lose its cohesive power even when raised to a white heat and then drenched with water.

Broken brick or stone, for the aggregate, stand fire better than breeze, which will burn away under very high temperatures.[1]

Slag cement is likely to be largely used for concrete floors in this country. It is cheaper and lighter than Portland cement, while its fire-resisting properties exceed those of Portland cement or gypsum.[2]

Plaster also resists fire well, especially when it is nearly entirely made with gypsum, as in the Hitchins Company's and Robinson's plasters.

Stone is a very bad material for fireproof structures; when subjected to great heat it suddenly cracks and gives way without warning. For this reason arches of fireproof construction should never rest upon projecting stone corbels.

In the Chicago fire, sandstone was found to stand better than limestone. Granite was quite disintegrated, or, under less heat, scaled.[2]

Silicate cotton, slag wool, and similar materials are fireproof, and very useful for pugging floors or partitions.

C, COST.—Under this head must be considered not only the cost of the floor itself but the expense it leads to.

Thus a deep floor will involve extra height of walling, and an arched floor, having a thrust upon the walls, will necessitate their being of extra thickness.

D, STRENGTH.—The floor must of course be strong enough to bear the weights it may be required to carry.

This can easily be arranged for, as it is a mere question of the thickness of arches and dimensions of the girders, and other parts of the floor.

E, PERMANENCY.—Floors of materials subject to decay from dry rot and other causes must of course be carefully avoided.

Recapitulating, we see that a good fireproof floor should be of good fire-resisting material—all ironwork being protected by non-conductors—that it should not lead to expense in other parts of the building, should be strong enough to carry the weights required to be placed upon it, and not liable to decay.

[1] Lawford, *Transactions*, Society of Engineers, 1888.
[2] Gass, *Transactions*, R.I.B.A., 1886, p. 134.

The student should test each floor described by seeing which it possesses of the characteristics described above. In selecting a floor for any particular purpose some of these characteristics will be more important for that purpose than others, and it is impossible to say abstractly that any system is the best under all circumstances.

DIFFERENT FORMS OF FIREPROOF FLOORING.

A great many different forms of fireproof flooring have been proposed and made use of during the last few years.

They may be generally classed under four heads.

A. Arches of brick or concrete supported upon walls or girders.

B. Hollow bricks or tubes supported between girders and filled in with concrete.

C. Concrete filled in between and around girders.

D. Solid timber of considerable thickness.

E. Iron plates resting on girders.

Arched Systems.

Girders and Brick Arches.—Among the earliest forms of fireproof floors were those consisting of brick arches of small or moderate span, supported by cast- or wrought-iron girders.

Such constructions are still in use for mills, warehouses, sugar factories, and other buildings, where great weights have to be stored.

The cast-iron girders shown in Fig. 257 are of a section frequently used in the earlier forms of floors, but they are superseded in modern practice by mild steel joists or girders.

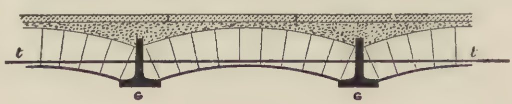


Fig. 257.

The girders may be placed from 4 to 12 feet apart; the arches turned from one to the other; the spandrils filled in and levelled up with concrete, and covered with a floor of any material.

A tension rod, *t t*, unites the girders, and prevents their yielding under the thrust of the arches. The nearer the tension rod is to the springing of the arch the better, but it is frequently kept high up within the arch in order that it may not be visible.

The tension rod is often used only for the outer arches of a series; these, being thus prevented from yielding, form an abutment for the others.

In arches of a larger span the thickness of the brickwork may be increased toward the haunches, as shown in Fig. 258.

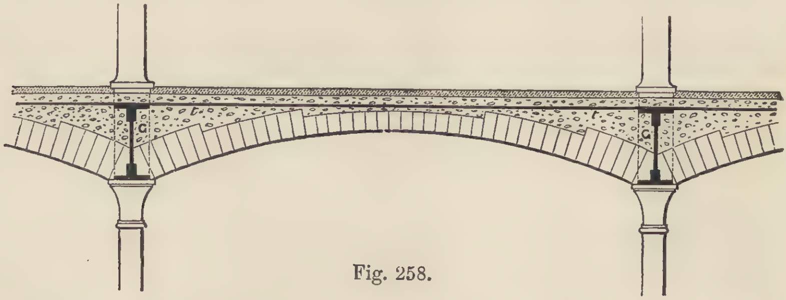


Fig. 258.

This increase of thickness is useless unless the extra rings are bonded in with the others, or built with bricks the full depth of the arch, which amounts to the same thing.

Sir W. Fairbairn recommends that the rise of such arches should be $\frac{1}{10}$ the span for floors of mills, and $\frac{1}{8}$ the span for warehouse floors to carry heavy weights.

Fig. 258 shows an arch of about 10 feet span, carried by wrought-iron plate girders, with angle iron flanges. These girders run at right angles to the arches, their ends rest upon the heads of columns, and the girders are laterally tied together by flat iron bars, *t t*, secured to their upper flanges.

Whichcord's Fireproof Blocks.[1]—It will be seen that in the systems above described the lower surfaces of the iron girders are exposed to the direct action of fire.

To prevent this, the late Mr. Whichcord imbedded them in fireclay blocks, which protect them from fire, and, at the same time, form skewbacks for the arches.

Fig. 259 shows in section a rolled girder with protecting fire blocks, BB. These are made in lengths of 9 inches, and with a minimum thickness at any point of $1\frac{1}{2}$ inch of fireclay, which has been found to resist the greatest heat to which such a structure is likely to be subjected.

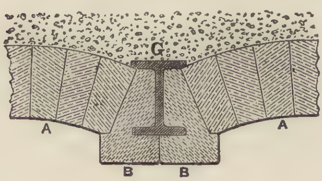


Fig. 259.

Where ceiling joists are used, they may be supported on the lower ledges of the fire blocks.

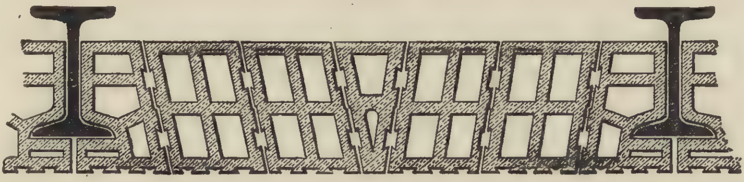
Doulton-Peto System, Fig. 260.—In this the blocks or voussoirs of the arch are of hollow fireclay blocks, which are stated

[1] Used at the National Safe Deposit Co.'s Warehouse.

to be $\frac{1}{3}$ lighter than bricks or concrete. The under sides of these are dovetail grooved so as to form a key for the plastering.

This flooring is capable of sustaining great weights; the girders are well protected; the arches being light may be of considerable span, though large spans increase the depth and cost of the floor, and, moreover, they do exert a certain amount of thrust upon the walls.

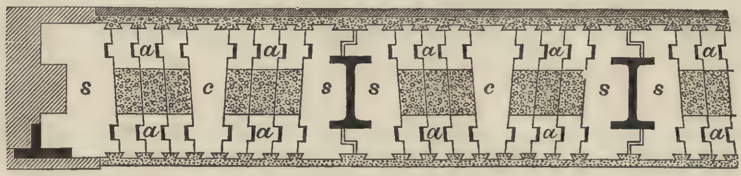
This flooring has been used at Whiteleys, The London Pavilion, National Provincial Bank, and in several warehouses.



DOULTON-PETO'S SYSTEM.
Section of 8-inch Flooring.
Fig. 260.

NORTHCROFT'S SYSTEM[1] consists of flat arches of specially moulded fire-bricks, resting upon fire-brick skewbacks supported by I iron girders.

These girders rest at the ends upon turned rollers, and are thus permitted to expand when heated.



NORTHCROFT'S SYSTEM.
Fig. 261.

In Fig. 261, *a a a* are the flat arches 6 inches deep, with a filling between of 6 inches of concrete. S S are the skewbacks, which are bedded in asphalte upon the I girders. The soffit is plastered to form a ceiling, and the surfaces of the floor finished off with parquet, cement, asphalte, or in any way that may be desired.

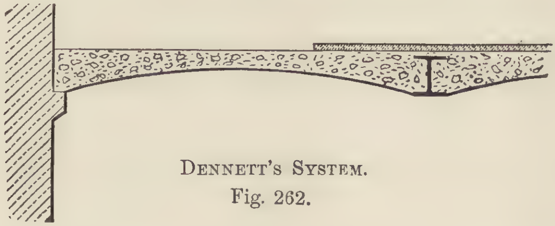
DENNETT'S FIREPROOF FLOOR consists of concrete arches supported where they abut upon the walls by projecting courses, and at intermediate points by rolled or riveted iron girders, as shown in Fig. 262.

The arches should have a minimum rise of 1 inch to every foot of width up to spans of 10 or 12 feet, and are sustained by centering until they are thoroughly set.

The concrete used has sulphate of lime (gypsum) for its

[1] From *Our Factories, Workshops, and Warehouses*, by R. H. Thwaite, C.E.

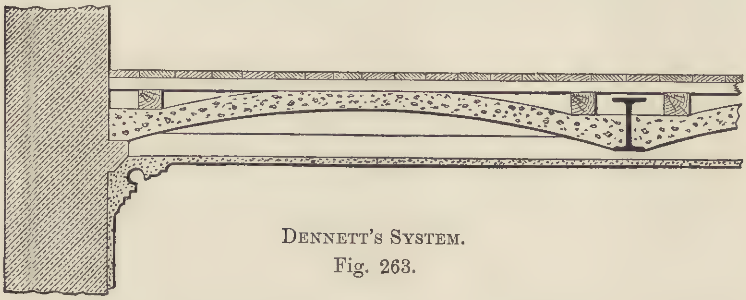
matrix. It has been proved that this substance does not lose its



DENNETT'S SYSTEM.
Fig. 262.

cohesive power even when it is raised to a white heat and then drenched with cold water.

The floor above the arch may be formed by simply bringing



DENNETT'S SYSTEM.
Fig. 263.

the concrete itself to a smooth surface. Joists may be nailed to fillets laid upon the concrete, in a similar manner to that shown in Fig. 263, or the surface may be paved as in Fig. 262.

The soffit of the arch may be finished at once with the setting coat of plastering;[1] or, if a flat ceiling is necessary, joists must be fixed to the lower flanges of the girders to carry the lath and plaster. The laths are not shown in Fig. 263.

Figs. 262, 263 are taken from Messrs. Dennett's pamphlet.

WILKINSON'S SYSTEM is very like Dennett's in form, but the arches are of concrete granite and the ceilings formed with fibrous plaster slabs.

This system has been used at Edinburgh University, several stations on North-Eastern Railway, by the War Department, and in many warehouses.[2]

LINDSAY'S ARCH SYSTEM consists of "Pumice concrete"[3] arches resting upon girders which are stiffened by truss rods, and whose

[1] Concrete arches are often laid upon a soffit of corrugated iron, which supports the concrete while it is being laid and protects it afterwards.

[2] Lawford, *Transactions*, Society of Engineers, 1889.

[3] See p. 191.

lower flange is protected from fire by an iron trough filled in with pumice concrete.

WOOD AND CONCRETE FLOOR.—Fig. 264 gives the section of a floor that was used for the office of the Board of Works in London, and which will resist fire to a considerable extent.

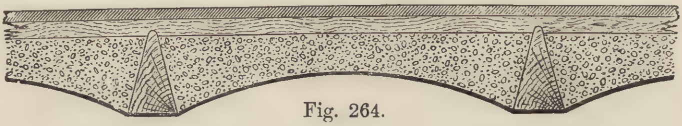


Fig. 264.

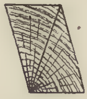


Fig. 265.

The joists are cut diagonally of triangular section, see Fig. 265, and are placed about 18 inches apart, so as to form skewbacks to concrete arches filled in between them.

BUNNETT'S SYSTEM[1] consists of hollow bricks of a peculiar shape laid in a flat arch from wall to wall, resting on angle irons held together by a tension rod passing through the bricks. The bricks are so arranged and formed laterally that each receives the support of six adjoining bricks. The under sides of the bricks are dovetail grooved to afford a key for the plastering.

TILE FLOORS consist of arches formed with flat tiles resting upon girders, in the same way as the brick arches above described. When the centering is fixed, the first course of tiles is laid dry, and then covered with cement; upon this a second, third, and fourth course are laid in the same manner. The spandrils are filled in with concrete, and the floor finished with joists and boarding, pavement, or in any way that may be desired.

Disadvantages of Arched Floors.—Arched floors, especially when composed of voussoir blocks, are complicated and heavy. The arches depend greatly upon one another, and if one gives way it may lead to the failure of the whole floor. In any case they exert a thrust upon the walls.

These disadvantages have led to the adoption of simpler forms of fireproof flooring.

Systems with Hollow Bricks or Tubes.

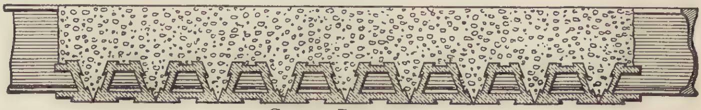
In order to avoid the lateral thrust of arches upon the walls, various systems have been proposed in which hollow bricks or

[1] Used at Grosvenor Hotel.

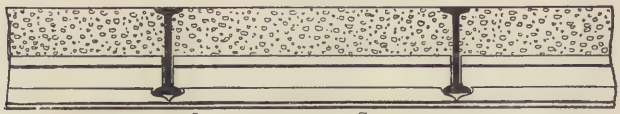
tubes are suspended by means of T or L irons between I joists, and the spaces between and above them filled in with concrete.

Systems with Hollow Bricks or Tubes.

HOMAN AND RODGERS' SYSTEM (Figs. 266, 267) consists of pur-



CROSS SECTION
Fig. 266.



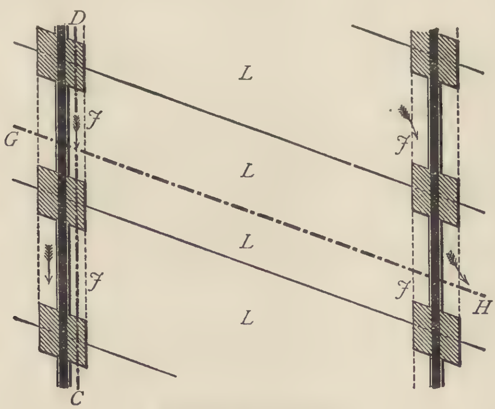
LONGITUDINAL SECTION
Fig. 267.

pose-made hard burnt bricks with moulded projections, protecting the iron joists upon which they rest, and filled in with concrete.

As the concrete is tough the boarding of the floor may be nailed to it direct, but inch-sleeper fillets are recommended so as to leave a space for ventilation, gas and water pipes, etc.

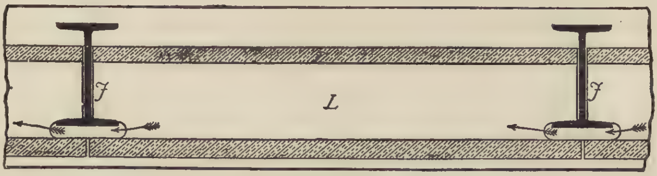
The soffits of the hollow bricks are dovetail grooved as a key for the plaster ceiling, and the depth of the finished floor is only 6 to 9 inches.

Fig. 267 is a longitudinal section, and Fig. 266 a cross section, of the floor.



FAWCETT'S SYSTEM.
Fig. 268.
Plan of ironwork and tubular lintels fixed ready for concreting.

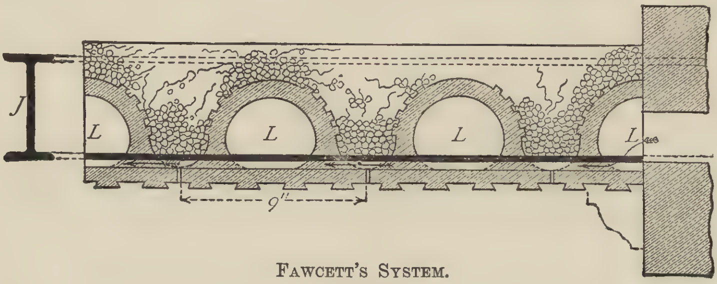
Fawcett's system (Figs. 268 to 270) *consists of Fireclay* or red clay tubes, or, as they are called by the inventor, "lintels," of the section shown at *L*, Fig. 270, which rest upon the lower flanges of steel or



FAWCETT'S SYSTEM.
Fig. 269.

Longitudinal section G, H, showing the tubular lintel encasing the joist, and the admission of cold air into the end of the tubular lintel.

iron rolled I joists 2 feet apart. The lintels are placed obliquely between the joists—their own diagonals being at right angles to the joists. The spaces between and above them are then filled in with concrete—their lower sides are dovetail grooved as a key



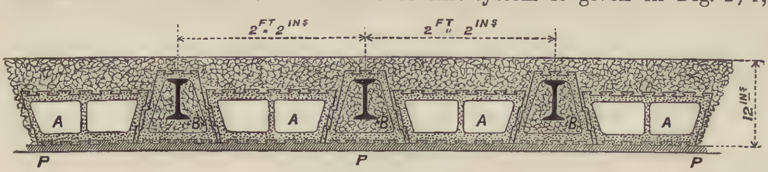
FAWCETT'S SYSTEM.
Fig. 270.

Transverse section C, D, showing the air passage under the joists and the admission of cold air into the side of the lintel.

for plastering. The weight of the floor is taken by the joists and concrete, the lintels acting merely as a permanent centering and casing to the ironwork, which is well protected.

This system has been used in numerous public buildings.

HORNBLOWER'S SYSTEM.—One form of this system is given in Fig. 271,



HORNBLOWER'S SYSTEM.
Fig. 271.

which shows the construction recommended by Mr. Hornblower for a floor to carry as much as two tons per superficial yard over a bearing of 18 feet.

A A are large hollow fireclay tubes ; B B are smaller tubes of the same

material, containing iron I girders as shown, and filled with fine Portland cement concrete, gauged 4 to 1 ; concrete is also packed in between and over the tubes ; P P is the plaster ceiling below, the key for which is afforded by indentations or grooves formed on the lower side of the tubes.

Girders filled in with Concrete.

In these systems there is no thrust upon the walls, and they are efficient if the ironwork is well covered by non-conducting material.

Fox and Barrett's Floors consist of mild steel girders placed about 20 inches apart, at right angles to which, and resting on their bottom flanges, are laid rough fillets or strips of wood 1 inch or $1\frac{1}{4}$ inch square, and about $\frac{1}{2}$ inch apart. Concrete is

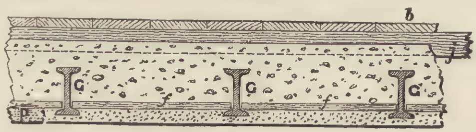
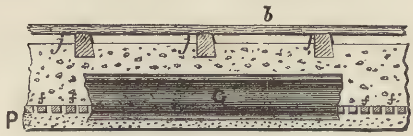


Fig. 272. Cross section.



Fox and Barrett's System.
Fig. 273. Longitudinal section.

then filled in between the joists—being supported by the fillets—which form a key to the plastering of the ceiling below.

In order to avoid all inflammable material, small earthenware drain pipes have been used instead of wooden fillets.

Fig. 272 shows a transverse section, and Fig. 273 a longitudinal section, of such a floor.

G G are the mild steel rolled girders, *f f* the fillets, P the plaster of the ceiling below.

The surface of the floor in the example shown is covered with boards laid upon the joists, *j j*, which are embedded half their depth in the concrete, and cut to a dovetail section to keep them firm.

Sometimes the concrete is filled in only up to the upper surface of the girders, and floor joists or paving laid upon it.

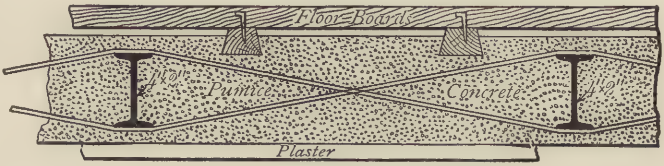
The concrete used for fireproof flooring of this kind should be of a quick-setting lime or cement, for until it has set its full weight comes upon the girders, but when it is solid it forms a series of flat arches between the girders and strengthens the floor.

If the concrete is thick, it should be applied in two layers to hasten its drying.

Care must be taken that the floor has a good abutment on each side, or is well tied together.

When the lower flanges of the girders are so wide that they would interrupt the key of the plaster and prevent its adherence, light ceiling joists are sometimes secured to the under side of the fillets at right angles to them. These are lathed and plastered in the usual way.

LINDSAY'S SYSTEMS.—*a, With* I *Girders.* The first of these (Fig. 274) consists of mild steel girders of I section, spaced from 18 inches to 3 feet apart, and trussed by pairs of rods about 18 inches



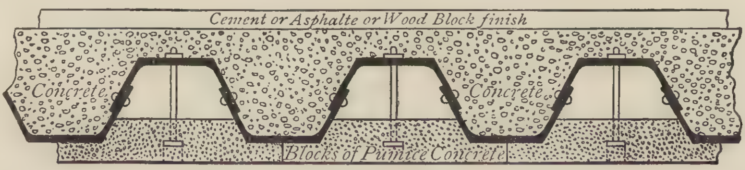
LINDSAY'S SYSTEM WITH I GIRDERS.

Fig. 274. Cross section for boarded floor with embedded sleepers.

apart, as shown in Fig. 274, which clip on to the lower flanges of the girders. Concrete made of coke breeze, mineral sand, and Portland cement—known as "pumice concrete"—is filled in and around the girders and rods. Among the advantages claimed for this floor are the composition of the concrete, which makes it 25 per cent lighter than ordinary concrete, also that if parts of the concrete are damaged the remainder is kept in position by the truss rods.

This system has been used for the Branch Bank of England, Royal Infirmary (Liverpool).

LINDSAY'S SYSTEMS.—*b, With Trough Girders* (Fig. 275). In this system mild steel rolled girders of trough section riveted



LINDSAY'S SYSTEM WITH TROUGH GIRDERS.

Fig. 275. Section of floor with concrete blocks under.

together are filled in with "pumice" concrete. When there is no substantial ceiling the lower surface of the ironwork is open to the action of fire, but this may be avoided by fixing pumice concrete blocks or slabs below instead of an ordinary plaster ceiling.

This system has been used at the National Liberal Club,

Prudential Assurance Company (Brook Street), Messrs. Maples, Dublin Museum, and by several Railway Companies.[1]

Strained Wire System.—In this, $\frac{1}{4}$ or $\frac{3}{8}$-inch rods, about 18 inches apart, are strained through holes in the webs of the joists, and fixed to the walls. A network is thus formed, and concrete is filled in around and below the joists so as to protect them. This system is also used for roofs.

Slabs of Pumice Concrete laid upon the lower flanges of joists, and formed with a projecting piece below to protect those flanges, make a fireproof floor which is quickly carried out.

For *Lindsay's Arch System*, see p. 186.

PIERSON'S SYSTEM, formerly *Gardner, Anderson, and Co.'s.*, is practically the same as Lindsay's I girder system with the truss rods omitted.

MORELAND'S SYSTEM is practically the same as Lindsay's trough system, but that the section of the troughs is rectangular instead of splayed.

DAWNAY'S SYSTEM consists either of $\frac{1}{2}$-inch square iron bars 12 inches apart, or of small 3-inch joists 16 inches apart, resting on the lower flanges of 5-inch binding joists in 7 feet bays; concrete of broken brick and Portland cement is filled in between and around the joists. This construction is suitable for spans up to 30 feet, the binding joists being strengthened according to the increase of span.

This system has been used at the Charing Cross Hotel, Colonial Institute, Exeter Hall, several Board Schools, and other buildings in London.

ALLEN'S SYSTEM consists of Portland cement concrete strengthened by iron bars. Bars about 3 inches by 1 inch are placed on edge across the building, 2 feet apart, and built into the walls on either side; across these are placed $\frac{1}{2}$-inch iron rods, also 2 feet apart, thus forming a network with meshes 2 feet square. A temporary scaffold is formed underneath the network, and the concrete—composed of 1 Portland cement to 4 of clinkers, slag, etc.—is thrown in to a depth of 4 inches; when it is set the scaffolding is removed.

Solid Timber Floors.

EVANS' AND SWAIN'S SYSTEM (Fig. 276) consists of timber joists spiked close together without any spaces between. The

[1] Cunnington, *Building News*, 15th March 1889.

depth of the joists varies from $4\frac{1}{2}$ inches for 8 feet spans to 11 inches for 30 feet spans. The spikes are about 18 inches apart, holes being bored for them to prevent splitting.

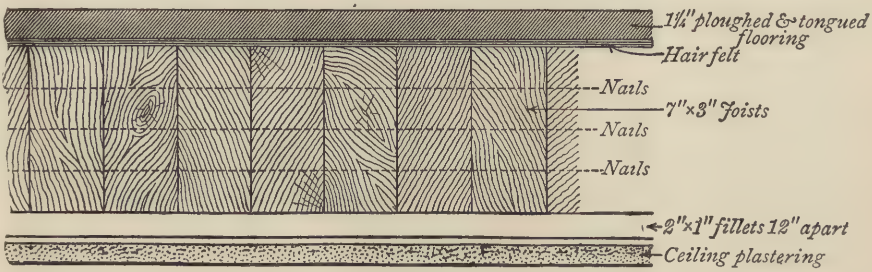


Fig. 276.

All cracks or shrinkages in the upper surface of the floor are filled up with a grouting of liquid plaster, while the plaster ceiling may be attached, as shown, to the under surface of the joists, alternate joists being less deep, so as to form a key, or it may be attached to laths upon fillets.

The advantages of this floor are, that it is simple, and composed entirely of timber in large scantlings and plaster, both of which offer a very considerable resistance to fire.

Girders with Plates.

Girders with Cast-Iron Plates.—Fig. 277 is the sectional elevation of a floor formed as follows :—

Wrought-iron rolled or built-up girders, G, span the room at from 10 to 15 feet central intervals.

Running at right angles to these, and resting upon them, are rolled joists, J J, about three feet apart. Upon the upper flanges of these joists are laid cast-iron plates shown in section at C, the joints being so shaped as to over-

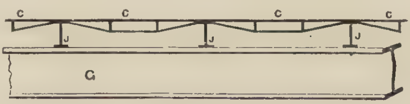


Fig. 277.

lap one another. The under side of these plates may be cast to a pattern, so as to form an ornamental ceiling.

Another row of cast-iron plates may, if required, be placed on the lower flanges of J J. The space between the two sets of plates may be left hollow so as to contain a stratum of air for coolness, or it may be filled with deafening composition, slag wool, or concrete.

The cast-iron plates are, of course, an objection to this system.

Girders with Wrought-Iron Plates.—Some years ago Sir W. Fairbairn recommended fireproof floors constructed with wrought-iron plates of arched form riveted to the lower flanges of the girders, and filled up to the level of the

floor with concrete, thus forming concrete arches of some 10 or 12 feet span with a wrought-iron lining to the soffit, supported at intervals by T iron ribs.

For smaller spans Mallet's buckled plates (see Part III.) have been used, their edges being riveted to the lower flanges of the girders upon which they are laid.

Weight and Cost of Different Systems of Fireproof Flooring.

The following Table is slightly modified from one given by Mr. Lawford in a paper read before the Society of Engineers.[1]

Approximate cost, weight, and safe load of each floor undermentioned—for 12 feet bearing.

Constructers.	Cost per Square Yard.		Weight per Square Foot.		Safe Load per Square Foot.
	Excluding Joists.	Including Joists.	Excluding Joists.	Including Joists.	
Arched.	*s. d.*	*s. d.*	lbs.	lbs.	cwt.
Dennett . . .	6 9	9 3	50	54	2
Doulton . . .	6 6	9 0	30	34	2
Wilkinson . .	6 0	7 6	50	52	2
Flat.					
Dawnay . . .		7 0		40	2
Gardner . . .		7 0		46	2
Homan and Rodgers		7 0		35	2
Lindsay, *a* . .		7 0		44	2
Evans and Swain .	10 6	No joists required.	20	No joists required.	7

American Systems.[2]

Arched Floors are much used in America—either brick arches supported by iron girders with "porous terra cotta,"[3] protecting blocks forming skewbacks, or arches of hollow blocks like those in the Doulton-Peto system (Fig. 260), or concrete arches like those of Dennett, but supported upon corrugated iron soffits.

Pugged Floors.—A section of one of these is shown in Fig. 278. It consists of wooden joists on which 2″ × 1″ strips support a course of bricks whose upper surface is covered with a layer of concrete, and upon which is a tiled or boarded floor. The ceiling is of terra-cotta tiles fixed to the joists by iron clips—jointed, and plastered below.

Slow-burning construction[4] is a term applied to the kind of floor generally used for mills and warehouses. These consist of solid beams or beams bolted together and 8 or 10 feet between centres,

[1] *Transactions*, Society of Engineers, 1888, p. 58.

[2] *Transactions*, R.I.B.A., 1886, p. 129, Mr. Gass's paper.

[3] Porous terra cotta is composed of clay mixed with combustible material, such as sawdust, cut straw, charcoal, etc. When baked the combustible material is consumed, leaving the terra cotta full of holes. It is fireproof, light, will hold nails, and gives a good surface for plastering (see Part III.)

[4] Woodbury's *Fire Protection of Mills*, New York.

upon these are laid floor planks 3 inches to $3\frac{1}{2}$ inches thick, over which is spread a layer of mortar $\frac{3}{4}$ inch thick, and over this again is laid a grooved and tongued floor of hard wood $1\frac{1}{4}$ inch thick. Sometimes two thicknesses of rosin-sized sheathing paper are substituted for the layer of mortar.

Fig. 278.

Fig. 279.

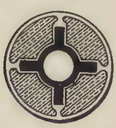


Fig. 280.

General.—Ironwork is always protected by terra-cotta blocks (Figs. 278-280[1]), plaster, etc. Ceilings are of terra-cotta tiles, or plastered on wire-cloth netting with $\frac{3}{8}$ inch squares. Exposed woodwork is protected by terra cotta or sheets of tin. Partitions are of hollow tiles.

Fireproof Roofing is not much in fashion in this country, though Lindsay's strained wire system has been used for part of the roof of the National Liberal Club, Branch Bank of England,[2] etc. In America it is sometimes constructed with porous terra-cotta blocks resting on T irons supported by I beams, or roof trusses are encased in terra cotta.

French Systems. — Wrought - iron girders were adopted for fireproof floors in Paris some time before they were known in England, and any notice of the different systems of fireproof flooring, however brief, would be incomplete without a reference to some of the plans originated in France.

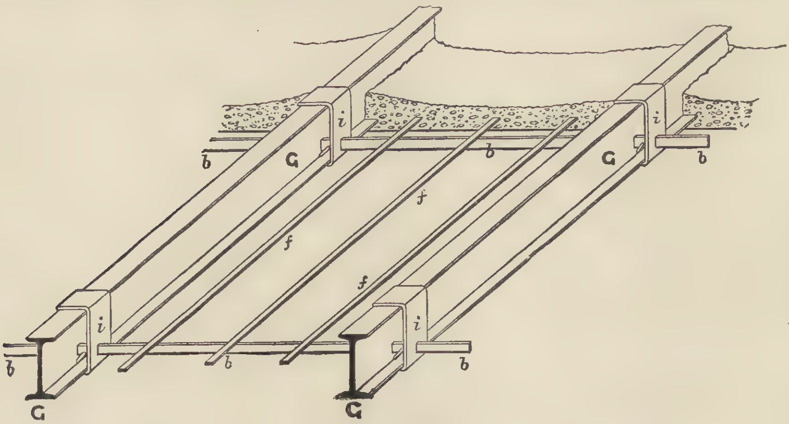
Though these are not commonly adopted in this country, some description of them may be useful in suggesting ideas for new systems, which may be arranged and modified in accordance with more recent experience.

Thuasne's System consists of I-shaped wrought-iron girders slightly arched, with a rise of about $\frac{1}{200}$, and placed at about 3 feet 3 inches central intervals. At right angles to them, and also 3 feet 3 inches apart, are laid flat iron bars or *interties*, *b b b*, whose ends pass through slits in wrought-iron bands, *i i i*, which embrace the girder at intervals of 3 feet 3 inches. The ends of the interties are secured by a pin passing through them on the farther side of the iron band.

[1] From *Transactions*, R.I.B.A., 1886, Pl. XVIII.
[2] Cunnington, *Building News*, 15th March 1889.

Crossing the interties at right angles are light iron rods called "fautons," *fff*; these are generally about $\frac{1}{2}$ inch square (not flat as shown in Fig. 281), placed about 9 inches apart, and bound to the interties with wire.

A flat centering or boarding is placed under this network, and coarse plaster of Paris is poured in upon it to a thickness of about 3 inches. This



THUASNE'S SYSTEM.

Fig. 281.

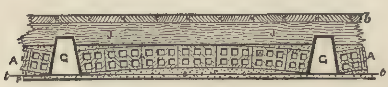
soon becomes hard, and serves not only to stiffen the floor but to form the ceiling, a fine coat being required on the under side as a finish to superior work.

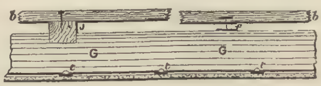
The girders are tied into the walls at each end by iron straps secured to vertical bolts in the wall.

Small square wooden joists are laid over the girders, and boarded in the usual way.

In some cases cast-iron chairs are used instead of the wrought-iron straps to carry the ends of the interties.

FER TUBULAIRE is the French name for a girder of peculiar form invented by M. Zorés and shown in Fig. 282.





FER TUBULAIRE.

Cross Section.
Fig. 282.

Longitudinal Sectional Elevation.
Fig. 283.

Floors of this kind were exhibited in the Paris Exhibition of 1857, and have been used for warehouses in this country.

They are thus described in the official report on civil construction.

"The 'fer tubulaire' may be described as being in section of the form of a capital A without the small triangular top. Those exhibited are said to be for a bearing of 20 feet, and are of the following dimensions—viz. $4\frac{3}{4}$ inches high, $2\frac{3}{8}$ inches wide at top, 4 inches wide at bottom exclusive of a small flange of $\frac{3}{4}$-inch projection on each side. The sides of the girder are $\frac{3}{10}$ths of an inch in thickness, and the top and flanges $\frac{7}{20}$ths. These girders are placed at a distance apart of 2 feet 8 inches from centre to centre, and are tied together at intervals of three feet by flat bar-iron ties of $\frac{3}{4}$ inch by $\frac{3}{10}$ inch bolted to the bottom of the flanges, and the flooring finished according to one of the following methods:

"Method No. 1.—Flat arches of hollow brick between the girders, with joists of 'fer à coulisse' (hereafter described) or of wood and wooden flooring, or for passages with the spandril filled in with plaster, and floored over with tiles ceiled underneath to soffit of flat arch.

"Method No. 2.—The spaces between the girders filled in with hollow blocks of plaster 4 inches deep. Flooring and ceiling as in No. 1.

"Method No. 3.—Wooden flooring as in No. 1, with ceiling on small iron laths hollow between floor and ceiling.

"Method No. 4.—Wooden flooring without ceiling."

The girders of this ∩ section (G G in Fig. 282) are said to possess the following advantages over those of the I form, commonly used:

"First, With equal weights they give a strength or resistance nearly double.

"Second, A floor constructed with these girders costs some 20 per cent less than one similar in all respects but constructed with girders of I section.

"Third, This form of joists requires no strutting, while the I girder requires lateral pressure to such an extent that it is said not to be employed to the best advantage unless absolutely filled in with either hollow brick arches or plaster, more than half its strength being dependent upon its lateral rigidity."

Fer à Coulisse.—This is a form of iron joist resembling the I section, but with three flanges, the second longer than the upper flange and close below it.

Fig. 283 shows at *f* this form of girder in use as a common joist.

The main girders of fireproof floors have also been made in France of this section.

The girders are placed about 20 inches from centre to centre, and the space between them filled in with hollow bricks, or a hollow block of plaster resting on the lower flanges. The advantages claimed for these girders are, that the second flange assists the top flange in affording the necessary resistance to compression when the girder is loaded, and that it also stiffens the girder in a lateral direction; and further, that it affords a convenient arrangement for laying the boarding at once without the intervention of joists, and without employing nails.

Fireproofing existing wooden floors.

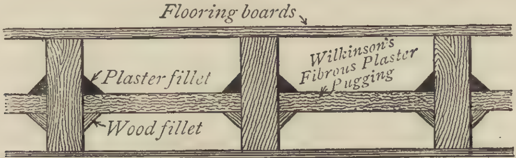


Fig. 284.

Messrs. Wilkinson have a system shown in section Fig. 284 by which existing wooden floors can be converted into "slow-burning constructions."

The ceiling and the pugging of the floor are formed of non-inflammable fibrous plaster slabs, $\frac{7}{8}$ inch thick, the latter laid in the usual way upon wood fillets fastened to the joists and secured by plaster fillets above.

The fibrous plaster slabs are made of coke breeze and plaster on a basis of cocoa-nut fibre. They make a very light floor which does not require such thick supporting walls as do floors of concrete (see also fireproof plastering, p. 182).

The systems of fireproof flooring that have been introduced or proposed at different times are almost innumerable. The shape of the girders has been varied in every possible way, and all sorts of materials used in connection with them.

Several new forms have been proposed during the last few years, but many of them have not been fully tried. The subject is one of great importance, and will no doubt be greatly developed.

Encasement of Girders and Columns in Concrete.

As above stated, it is necessary that all iron work should be protected from the fire by some non-conducting substance. Figs. 285, 286 show the method adopted by Messrs. Dennet and Ingle for encasing both columns and girders in concrete.

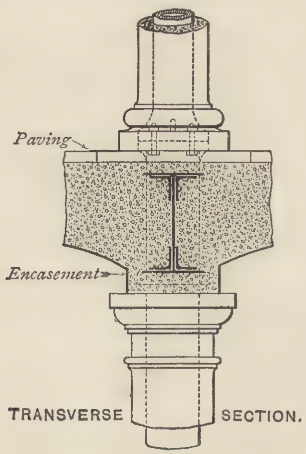


Fig. 285.

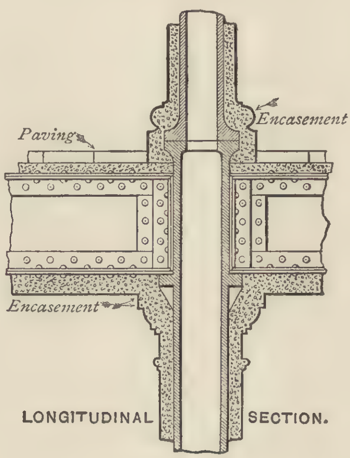


Fig. 286.

Chapter IX.

PLASTERERS' WORK.

Plastering consists in applying different compositions resembling mortar to walls and ceilings, in thin layers, so as to form smooth surfaces, for the sake of appearance and cleanliness.

The plaster may either be laid on the face of the wall itself, or it may be spread over a screen of laths fixed in any required position.

The latter operation only is technically known as "*plastering*," the application to the wall itself being called "*rendering*."

Plastering and rendering are applied in one, two, or three coats, according to the importance of the building and the degree of finish required.

Materials used by the Plasterer.—The materials used for plastering will be fully described in Part III.

In the following brief notes information is given sufficient only to enable the student to understand the processes described in this chapter.

Limes and Cements.—*Lime.*—The pure or fat limes are generally used for plastering, because in using hydraulic limes minute unslaked particles are apt to get into the work, and to *blow,* throwing out bits of plaster, and injuring the surface.

Plaster of Paris is calcined gypsum. When mixed with water to form a paste it sets very quickly, expanding as it sets, and attains its full strength in an hour or two.

Portland Cement is made from chalk and clay mixed together in water, then burnt and ground. It is the strongest cement in use, but sets more slowly than the other varieties.

Roman Cement, Medina Cement, Harwich, Calderwood, Whitby, Mulgrave's, and Atkinson's Cement, are all natural cements of the same description. They are made by burning nodules found in different geological formations. These cements set very rapidly, but attain no great ultimate strength.

Keene's, Parian, Martin's, and *Robinson's Cements,* are all manufactured by recalcining plaster of Paris with different substances.

These cements are useful only for indoor work; they set very quickly, and can be painted within a few hours.

Whiting is made by grinding white chalk to a fine powder.

SAND AND WATER.—Very clean sand and fresh water should be used for plasterers' work (see Part III.)

MIXTURES.—*Coarse Stuff* is a rough mortar, containing 1 or $1\frac{1}{2}$ part of sand to 1 of lime by measure, thoroughly mixed with long ox hair (free from grease and dirt), in the proportion of 1 lb. hair to 3 cubic feet of mortar.

Fine Stuff is pure lime slaked with a small quantity of water, and afterwards saturated until it is of the consistence of cream; it is then allowed to settle and the water to evaporate, until thick enough for use. For some purposes a small quantity of white hair is added.

Plasterers' Putty is lime dissolved in water, and then run through a hair sieve. It is very similar to fine stuff, but prepared somewhat differently, and always used without hair.

Gauged Stuff consists of from $\frac{3}{4}$ to $\frac{4}{5}$ plasterers' putty, and the remainder plaster of Paris. The last-named ingredient causes the mixture to set very quickly, and it must be gauged in small quantities. The proportion of plaster used depends upon the time to be allowed for setting, the state of the weather, etc., more time required in proportion as the weather is damp.

For cornices the putty and plaster are often mixed in equal proportions.

Stucco is a term vaguely applied to many mixtures containing common and hydraulic limes, also to some cements.

Common Stucco contains three or four parts sand to one of hydraulic lime.

Trowelled Stucco consists of $\frac{2}{3}$ fine stuff (without hair), and $\frac{1}{3}$ very fine clean sand.

Bastard Stucco is of same composition as trowelled stucco, with the addition of a little hair.

Rough Cast consists of sand, grit, or gravel, mixed with hot lime in a semi-fluid state.

Size is thin glue made by boiling down horns, skins, etc.

Double Size is boiled for a greater time so as to be stronger.

LATHS are thin strips of wood, generally fir, sometimes oak, split from the log, 3 or 4 feet long, about an inch wide, and varying in thickness according to their class.

Single laths	are about	$\frac{3}{16}$	inch thick.
Lath-and-half lath	"	$\frac{1}{4}$	"
Double laths	"	$\frac{3}{8}$	"

Lathing.—Laths to receive plaster may be fixed either in a horizontal position as for ceilings, vertically as a covering for walls and partitions, or in such a manner as to form inclined or curved surfaces.

Lathing Ceilings.—For this purpose the laths are nailed to the underside of the ceiling joists (see Figs. 286 and 350, Part I.), (or in many cases to the bridging joists; see Fig. 282, Part I.), which should, if necessary, be brought into a horizontal plane by adding slips of wood called "firrings."

The laths are fixed parallel to one another, and $\frac{3}{8}$ inch apart so that the intervals afford a key for the plaster. Every lath is secured by nails, one being driven through the lath wherever it crosses a joist or batten. The moist plaster passes between the laths, forming protuberances at the back—these harden and form what is known as the "*key*," which prevents the plaster from falling away from the laths and keeps it in position. Care should be taken that the ends of the laths do not overlap one another, and that they are attached to as small a surface of timber as possible, so that the key may not be interrupted.

If the joists are of wood, a narrow fillet may be nailed along the under side of each to receive the laths, so as to interfere with the key of the plaster as little as possible.

The laths should be laid in "bays," so as to break joint in portions 3 feet wide (see Fig. 287).

The thickest laths should be used for ceilings, and for very important work they should be nailed with zinc nails, so that there may be no danger of their oxidising, and the rust showing on the surface.

Battened Walls[1] are so called because wooden battens about 2 to $2\frac{1}{2}$ inches wide, and from $\frac{5}{8}$ to 1 inch thick, are fixed vertically at central intervals of about 12 inches, to receive the laths.

The battens are nailed to wood plugs in the wall, except where flues occur, in which case they should be secured by iron holdfasts.

The laths are nailed as above described. They should be fully $\frac{3}{4}$ inch clear of the inside of the wall, and about $\frac{3}{8}$ inch apart—thus affording a key which is sufficient to support the plaster in its vertical position.

Lath-and-half laths should be used for walls and partitions subject to rough usage, and single laths for ordinary walls.

Walls likely to be damp should be battened, as the clear air-

[1] Sc. *Strapped walls.*

space between the masonry and the lathing insures the plastered surface being constantly dry; but battened walls harbour vermin. the woodwork is subject to decay, and is injurious in case of fire.

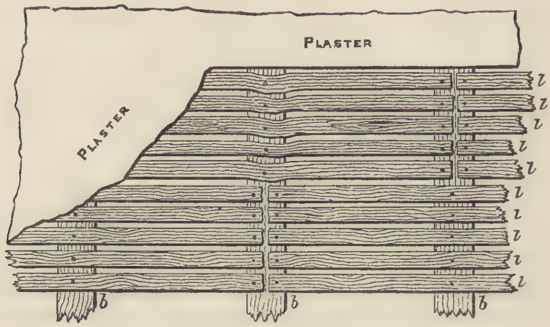


Fig. 287. *Elevation.*

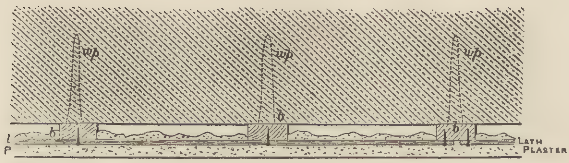


Fig. 288. *Sectional Plan.*

Figs. 287, 288 show a sectional plan and an elevation of a portion of a battened wall, with some of the plaster removed, in order to show the laths *l l* and battens *b b* below.

The laths are shown as breaking joint in bays. This is not absolutely necessary for walls, but is often done in vertical work as well as for ceilings.

Counter-lathing is necessary when plaster has to be applied close to a flat surface, such as that of a large beam. In such a case laths are nailed on to the surface of the beam about a foot apart, and across these is nailed the lathing to receive the plastering.

This second layer of laths is termed *counter-lathing.* Being clear of the surfaces of the beam, a key is afforded, and the plaster adheres to the first layer of laths, which it would not do if they were nailed on to the beam itself.

Brandering is a Scotch term applied to a kind of counter-lathing. It has already been described at page 141, Part I.

Plastering.—One-Coat Work; known as "*Lath and Plaster one Coat;*" or, "*Lath and Lay.*"—This consists of a layer of "coarse

stuff" of an uniform thickness, spread over the laths with a smooth and even surface. The plaster should be stiff enough to hold together, but just sufficiently soft to pass between the laths, being worked well in between them with the point of the trowel, and bulging out behind the laths into excrescences, which form a key, and keep the plaster in position.

This is the cheapest kind of plastering, and is used only in inferior buildings, or behind skirtings, plinths of partition shutters, window backs, etc.

In some parts of the country one-coat work is never used to cover lathing, but only for rendering on walls.

TWO-COAT WORK; described as "*Lath, Plaster, and Set;*" or, "*Lath, Lay, and Set.*"

1*st Coat.*—The first coat is laid upon the laths as above described, but the surface, instead of being smoothed, is roughed over by scratching it with a birch-broom, so as to form a key for the second coat.

Setting.—The second coat, or "setting," is a thin layer of fine stuff, or putty, or gauged stuff, and should not be trowelled on till the first layer is stiff. If the latter has become very dry, it must be moistened before the second coat is applied, or the latter in shrinking will have its moisture sucked out, crack, and fall away. As the fine stuff is laid on, the surface is smoothed by drawing backwards and forwards over it the wet brush used for damping the first coat.

THREE-COAT WORK.—Described as "*Lath, Plaster, Float, and Set;*" or, "*Lath, Lay, Float, and Set.*"

Pricking-up is the name given in this case to the first coat, which is laid as before described; but in order to form a good key for the next coat the surface is scored over with the point of a lath in deep scratches, crossing each other diagonally in sets of parallel lines about 3 or 4 inches apart.

Scratching tools, with several points, are sometimes used.

Floating.[1]—The second, or "floated" coat, is applied when the pricking-up is sufficiently dry to resist pressure.

It consists of fine stuff, with the addition of a little hair, and derives its name from its being laid on with "floats" in the following manner:—

In order to ensure the surface of the plaster being in a true plane, narrow bands or "screeds" of plaster, about 6 or 7 inches wide, are formed at the angles, and at intervals of from 4 to 10 feet

[1] Sc. *Straightening*

on the wall or ceiling. The surfaces of these are then brought into the required plane by passing long straight-edges over them.

Horizontal screeds for ceilings should moreover be levelled, and vertical screeds "plumbed" up from the skirting grounds (see page 126), before proceeding farther.

The spaces between the screeds are then "filled out" flush with the fine stuff, and smoothed off with straight-edges, or with a large flat board, having two handles at the back, and known as a "Derby float."

The surface is then gone over with a smaller hand float, and any defects made good by adding a little soft stuff.

Setting.—Before applying the third coat or setting, the floated surface should be scratched over with a broom, and then allowed to become perfectly dry.

The setting is varied in composition to suit the nature of the finish intended for the surface.

If the surface is to be papered, it should be "set with fine stuff;" if it is to be whitened, it should be "set with putty and washed sand;" and if it is to be painted, it should be finished with "trowelled stucco" or plaster.

"Set with Fine Stuff."—For surfaces to be papered the setting coat should be of fine stuff containing a little hair, and the finished work would be described as "Lathed, Plastered, Floated, and Set with Fine Stuff."

"Set with Putty and Plaster."—If the wall or ceiling is to be whitened or coloured, the third coat should be of plasterers' putty mixed with a little fine sand, and sometimes with a little white hair.

If required to set quickly, especially in damp weather, from $\frac{1}{6}$ to $\frac{1}{3}$ plaster of Paris is added to the stuff, which must be gauged (or mixed) in small quantities (see Gauged Stuff, p. 200).

This work, when finished, would be known as "Lathed, Plastered, Floated, and Set with Putty and Plaster;" or it would also come under the general designation of *Gauged Work.*

Great care should be taken to ascertain that the floated coat is dry before this setting is applied, otherwise the coats will shrink unequally, and the last coat will be full of cracks.

Rendering is the term used for the process of applying plaster or cements to the naked surface of walls.

With regard to plaster, it is applied in exactly the same way as upon laths, excepting a slight difference in the first coat.

The surface of the wall to be rendered should be rough so as to form a key to which the plaster will firmly adhere. This may be secured by leaving the mortar joints unstruck and protruding when the wall is built; or the joints may be raked and the face hacked and picked over to give it the necessary roughness.

Rough Rendering is the first coat laid to receive more finished work.

It is of coarse stuff, but contains a little less hair than that used on laths, and is applied in a moister state, which causes it to adhere better to the wall.

The holes and crevices in the wall should be entirely filled up in applying this coat, but the surface of the plaster need not be scratched or scored over.

Floating and Setting are performed in exactly the same way as upon laths.

Gauged Work is formed by the addition of a proportion of plaster of Paris to any coat of plaster, in order to cause it to set more rapidly. Unless the process is very carefully conducted cracks will occur in the plaster. The quantity of plaster added depends upon the rapidity of setting required, the dampness of the weather, etc.

Cornices, Mouldings, and Ornaments, should be as light as possible.

If they do not project more than 2 inches, a backing of coarse stuff will be sufficient to support them; but if the projection is 6 or 8 inches, or more, brackets of wood, roughly cut to the section of the intended cornice, must be fixed along the wall at intervals of 10 or 12 inches. Upon these laths are nailed and "pricked up"—that is, covered with a thick coat of coarse stuff, so that a rough edition of the future cornice is produced. A mould made of zinc, or of beech with zinc or brass edges, is then for the time "muffled" by covering the profile edge with a layer of plaster of Paris about $\frac{1}{8}$ inch thick. The mould is then drawn along over the surface of the rough cornice of coarse stuff already formed. It is guided by battens fixed along the lines where the cornice will cut the ceiling and wall, and the effect produced by it is to remove the superfluous stuff and leave the cornice moulded approximately to the form required, the surface all over being about $\frac{1}{8}$ inch within the intended profile. The muffling is then removed from the mould, and the surface of the cornice covered with gauged stuff, over which the mould is worked until the exact form of the cornice is produced.

As the stuff sets very quickly, it should be frequently sprinkled, and portions between projections or other breaks in the line should be finished off at once.

Where a portion of the moulding projects 3 or 4 inches beyond the general surface, it may be sustained by nails driven into the wall or bracket about 6 inches apart, and connected by tarred string.

Mitres in angles and small breaks are finished by hand, and indentations are left for enrichments, which may be cast in plaster of Paris, or composition, and cemented into their place.

These indentations in the plaster are formed by projections left on the mould.

Ornaments of various kinds are made of plaster of Paris cast in bees'-wax moulds. When large and heavy they should be secured by screws to woodwork.

Carton pierre, or Papier Maché, consisting of paper formed into pulp and forced into moulds, is also used for ornaments. Though not capable of receiving so sharp an outline as plaster of Paris, it is more easily transported without breaking, lighter, easier to fix, and very useful—especially in the country, where skilled workmen to cast plaster ornaments are not easily obtainable.

There are several other materials used for making the mouldings and ornaments required by the plasterer, which it would be beyond the province of these Notes to describe.

Fig. 289 shows a cornice at the angle of a room in sectional elevation.

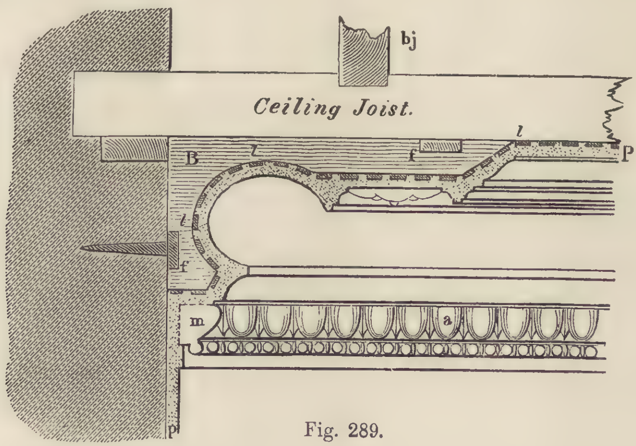


Fig. 289.

B is the rough bracket cut approximately to the shape of the cornice. This bracket is attached to the fillets *ff*, which are

fixed as shown, and carefully levelled. In some cases the bracket is nailed to the bottom or sides of the ceiling joists, and it is very frequently built into the wall, as shown at C in Fig. 290.

l l are the laths nailed to the bracket to form the surface and key for the plastering.

m is the moulding, which is made separately, and fixed (after the cornice is run and set) into the recess left for it, shown in Fig. 289 in dotted lines.

An ornament is also shown in the recess left in the soffit of the cornice. Holes are broken through the plaster forming this soffit, so that the soft plaster at the back of the ornament may pass between the laths themselves, and thus form a key, which secures it directly to the lathing.

The coved portion of the cornice is sometimes formed in papier maché or light plaster casts, and fixed without any supporting brackets, being fitted in between the projecting mouldings above and below, and secured with plaster of Paris.

Large Coved Cornices are supported by brackets or cradling, built up of pieces of board. Two or more are used, according to the size of the cornice, and the surface is covered with lathing, and finished in the same way as small cornices.

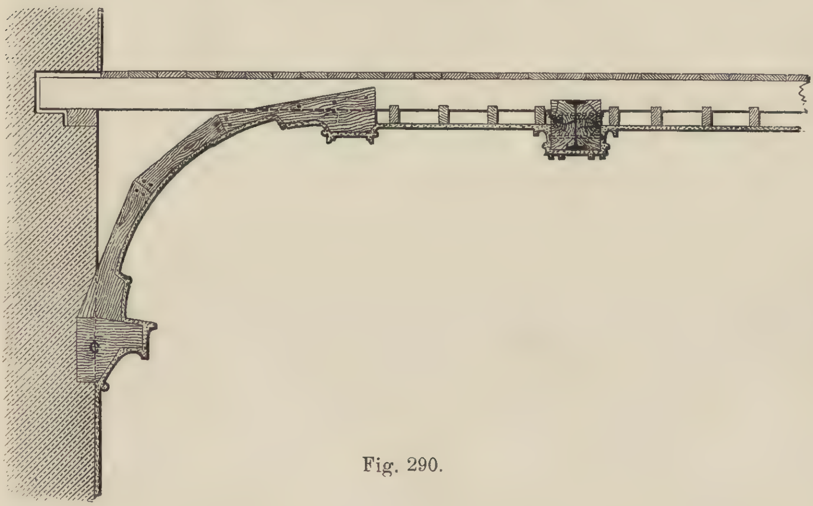


Fig. 290.

Fig. 290[1] shows a bracket built up in three pieces, which abut

[1] The scale of this figure is so small that neither the lathing nor counter-lathing is shown.

against one another, other pieces being nailed over the joints, the upper extremity being nailed to the joists of the floor above, and the lower end resting upon the rough bracket of the projecting cornice below, which is built into the wall.

This figure shows also the method of covering a beam projecting below the surface of the ceiling. The sides and soffit of the beam are counter-lathed, plastered, and decorated by mouldings struck on the plaster, or attached to it.

In some cases the beam is covered with cradling, which makes it up to the size required for the design of the decoration, and, by keeping the laths at a distance, affords a key without counter-lathing.

"Very large projecting mouldings and cornices inside buildings are even made of coarse canvas strained over a light framework, and washed over with gauged stuff. They are easily carried up and fixed in position."[1]

Rendering in Cement.—The wall to be rendered should itself be dry, but the surface should be well wetted, to prevent it from absorbing at once all the water in the cement; it should also be sufficiently rough to form a good key for the cement.

Screeds may be formed on the surface, and the cement should, if possible, be filled out the full thickness in one coat, and of uniform substance throughout.

Any excess of cement in projections, mouldings, etc., should be avoided, by dubbing out with bits of brick.

When cement is put on in two or three coats, the coats already applied should on no account be allowed to dry before the succeeding layers are added.

The coats last applied are very liable to peel off under the effects of frost or exposure.

Many of the quick-setting cements, such as those mentioned below as adapted for internal work, are rendered in one thickness of cement and sand, and the face afterwards finished and brought to a surface with neat cement.

Sand may be added with advantage to most cements, to prevent excess in shrinkage and cracking; sometimes a very large proportion is used (see Part III.)

External Work.—The material best adapted for rendering the external surfaces of walls is Portland cement. Other materials

[1] Seddon's *Notes.*

such as Roman cement, are, however, frequently used, but have not the same adherence, appearance, or weathering properties.

The objection to Portland cement, from an economical point of view, is its first cost, the greater labour required in using it as compared with that necessary for other cements, and also the time frequently wasted upon it, for, in consequence of its setting slowly, there is a tendency for the men to go on working it too long.

In order that it may set as quickly as possible, the less heavy varieties should be selected for rendering (see Part III.)

External rendering is often marked with lines, so as to represent blocks of ashlar stone.

Both Portland and Roman cement are mixed with a good proportion of sand for external work.

The Portland cement may be used in the proportion of 1 cement to 3 sand, and the Roman cement with 1 part of sand to 1 of cement for upright work.

For cornices, mouldings, etc., about half the quantity of sand should be used, but some is required to prevent cracking.

Internal Work.—Parian, Keene's, Martin's cement, and others of a similar character, are eminently adapted for internal work.

The treatment of the several descriptions varies slightly, but they are generally laid in a thin coating of about $\frac{1}{8}$ inch depth on a backing of Portland cement and sand. In some cases the backing is formed of the quick-setting cement itself, mixed with 1 to $1\frac{1}{2}$ of sand.

Most of them can be brought to a beautiful hard polished surface, and are ready to receive paint in a few hours.

These cements are largely used, not only for rendering walls, but for forming skirtings, mouldings, pilasters, angle beads, and other internal finishings of a building.

Portland cement is also used for internal work often with a very large proportion of sand, as much even as 9 parts of sand to 1 of cement being recommended.

Stucco.—*Common Stucco*, composed of $\frac{3}{4}$ sand and $\frac{1}{4}$ hydraulic lime, used to be greatly in vogue for outside work, but has now been almost superseded by the various cements introduced during the last few years.

To receive stucco, the surface of the wall should be rough to form a key, thoroughly wetted, and freed from dust. The stucco is then laid on in a fluid state with a brush, like whitewash, after

which a coat may be applied as in common rendering, unless the work is to be floated, in which case screeds must be formed round the margin of the wall, and vertically, at intervals of 3 or 4 feet throughout its length. These are filled out with stucco, which is smoothed by a straight-edge passed over it to remove any superfluous plaster, and then well rubbed with the hand-float and brought to a hard and glossy surface.

When cornices are to be formed, projecting bricks or tiles must be left to support them. These are covered with stucco, on which the moulding is run as in internal work.

Plaster of Paris quickens the setting of the stucco, but should not be used for outside work, as it will not stand exposure.

Rough Stucco is an imitation of stone. It is spread in a thin coat on a floated ground, which should be in a half-dry state, and is then gone over with a hand-float covered with a piece of felt, which raises the grit of the sand and gives the surface of the work the appearance of stone.

This also has been superseded by cement, which is treated in the same way when it is required to have a rough surface.

Trowelled Stucco, consisting of $\frac{2}{3}$ fine stuff and $\frac{1}{3}$ sand, is worked upon the floated coat, which must be perfectly dry before it is applied. The stucco is beaten and tempered with water until it is of the consistency of thin paste. It is then spread with a large trowel over the surface, to the thickness of about $\frac{1}{16}$ inch, as evenly as possible, and in small portions of about 2 or 3 square yards. The surface is then wetted and rubbed down with the hand-float (being sprinkled with a wet brush during the operation), until a surface is produced as hard and smooth as that of polished marble.

This process is used for surfaces to be painted, and for superior ceilings to be finished white. It is not so strong as the finishing with fine stuff.

Bastard Stucco is, like trowelled stucco, laid upon the second or "floated coat," but it is slightly different in composition, as it contains a little hair, is not hand-floated, and is finished with less labour than the other.

This and trowelled stucco are chiefly used for inside work intended to be painted.

Selenitic Plaster[1] is made by adding a small proportion of plaster of Paris to hydraulic limes, which are then known as "prepared Selenitic Limes."

[1] Selenitic material has been used in the Imperial Institute.

The effect of this is to stop the slaking of the lime, and to convert it into a kind of cement.

The following instructions for its preparation are from the circular of the patentees :—

"*If prepared in a Mortar Mill.*—1*st,* Pour into the pan of the edge-runner four full-sized pails of water.

"2*d,* Gradually add to the water in the pan 2 bushels of prepared selenitic lime, and grind to the consistency of creamy paste, and in no case should it be thinner.

"3*d,* Throw into the pan 10 or 12 bushels of clean sharp sand, burnt clay, ballast, or broken bricks, which must be well ground till thoroughly incorporated. If necessary, water can be added to this in grinding, which is preferable to adding an excess of water to the prepared lime before adding the sand.

"When the mortar mill cannot be used, an ordinary plasterer's tub (containing about 30 or 40 gallons) or trough, with outlet or sluice, may be substituted.

"*If prepared in a Plasterer's Tub.*—1*st,* Pour into the tub 4 full-sized pails of water.

"2*d,* Gradually add to the water in the tub 2 bushels of prepared selenitic lime, which must be kept well stirred until thoroughly mixed with the water to the consistency of creamy paste, and in no case should it be thinner.

"3*d,* Measure out 10 or 12 bushels of clean sharp sand or burnt clay ballast, and form a ring, into which pour the selenitic lime from the tub, adding water as necessary. This should be turned over two or three times, and well mixed with the larry or mortar hook.

"Both the above mixtures are suitable for bricklayers' mortar or for first coat of plastering on brickwork.

"*N.B.*—Plastering on brick can be floated (or straightened) in one coat, and requires no hair.

"*For Plastering on Lath Work.*—To the same quantities of water and prepared lime, as given, add only 6 or 8 bushels of clean sharp sand and 2 hods of well-haired lime putty; the hair being previously well hooked into the lime putty. When the mill is used, the haired putty should only be ground sufficiently to ensure mixing. Longer grinding destroys the hair.

"Lime putty should be run a short time before being used, to guard against blisters, which will sometimes occur.

"This mixture will be found to answer equally well for ceilings

as for partitions. If the sand is very sharp, use only 6 bushels of sand for covering the lath, and when sufficiently set, follow with 8 bushels of sand for floating (or straightening).

"*Setting Coat and Trowelled Stucco.*—For common setting (or finishing coat of plastering), the ordinary practice of using chalk lime putty and washed sand is recommended. But if a hard selenitic face is required, care must be taken that the prepared selenitic lime be first passed through a 24 by 24 mesh sieve, to avoid the possibility of blistering, and used in the following proportions:—4 pails of water; 2 bushels of prepared selenitic lime (previously sifted through a 24 by 24 mesh sieve); 2 hods of chalk lime putty; 3 bushels of fine washed sand.

"This should be treated as trowelled stucco; first well hand-floating the surface, and then well trowelling. A very hard surface is then produced.

"*Selenitic Clay Finish.*—5 pails of water; 1 bushel of prepared selenitic lime; 3 bushels of prepared selenitic clay; 2 bushels of fine washed sand; 1 hod of chalk lime putty.

"This mixture, well hand-floated to a fair face, and then well trowelled, will produce a finished surface equal to Parian or Keene's cement, and will be found suitable for hospital walls, public schools, etc. Being non-absorbent, it is readily washed.

"The use of ground selenitic clay improves the mortar, and renders it more hydraulic.

"When the selenitic clay is used, 2 bushels may be added to 1 bushel of prepared selenitic lime, the proportion of sand, ballast, etc., being the same as for prepared selenitic lime. The use of selenitic clay effects a considerable saving, as it is much cheaper than lime.

"*For outside Plastering* use 6 or 8 bushels only of clean sand, and for finishing rough stucco face use 4 or 5 bushels only of fine washed sand, to the proportions of lime and water given.

"*Plastering on Walls* can be finished by the above processes, as two-coat work in 24 hours, while the ceilings can be floated immediately after the application of the first coat, and be set in 48 hours."

The advantages of this material for plastering are—its cheapness, as it can be used with a very large proportion of sand; its quick setting, which enables the coats to be applied rapidly in succession, and prevents delay.

Selenitic lime or mortar should not be used in conjunction with

gauged stuff for cornices, screeds, etc. No more mortar should be gauged than can be used the same day.

In applying selenitic plaster to quartered partitions or ceilings, care must be taken that the supporting woodwork is thoroughly seasoned, for the plaster is rigid and will be cracked if the timber warps and twists.

Rough-Cast is used as a cheap protection for external walls.

The surface of the wall is first "pricked up" with a layer of "coarse stuff," upon which a coat of similar composition is evenly spread; while this is wet, and as fast as it is done in small portions, rough-cast (p. 200), in a semi-fluid state, is thrown upon it with large trowels from buckets, forming a rough adhering crust, which is at once coloured with lime-wash and ochre.

Depeter consists of a pricked-up coat with small stones pressed in while it is soft, so as to produce a rough surface.

Depretor is the name for plaster finished so as to represent tooled stone.

Surfaces.—*Whitewash* is a mixture of any common white fat lime with water. It is used for common walls and ceilings which have to be whitened frequently, and for sanitary purposes.

Whitening is a mixture of whiting and size, used for whitening ceilings and inside walls. It will not stand the weather.

Colouring for very common work is made by mixing naturally-coloured earths, such as ochres, with whitewash.

Distemper is made with whiting and size. Any colouring matter may be added, being first ground in water and added to the whiting. Sometimes a little alum and soft soap are substituted for the size.

It is used for colouring walls and whitening ceilings; but is not fit for outdoor work, as it will not stand the weather.

Distemper is generally laid on cold, and at about the consistency of trembling jelly.

Not more than two coats are required—the first should be thin, and should contain a double quantity of size.

White lead is sometimes substituted for the whiting to produce a smoother surface; and for outside work boiled oil is sometimes added to ordinary distemper to make it weather better.

Pugging is a coat of coarse stuff about 2 or 3 inches thick laid on boards fixed between the joists of a floor. It is intended to prevent sounds and smells from passing from one room to the other (see Part I.), but is rather apt to lead to decay in the woodwork.

Scagliola is chiefly used for imitation marble pilasters and columns.

For the latter a "cradle" is first formed of wood, lathed over, and "pricked up" with lime and hair mortar.

After this has set and is quite dry it is covered with a floated coat consisting of plaster of Paris mixed with various colouring matters in a solution of glue or isinglass, to give greater solidity and to prevent the plaster of Paris from setting too quickly. When the surface is thoroughly hard, it is rubbed with pumice stone, being kept damp and clean with a wet sponge; it is then rubbed with tripoli and charcoal, then polished with a felt rubber dipped in tripoli and oil, and lastly finished by means of a piece of felt dipped in oil only.

This substance has been to a great extent superseded by the use of Keene's and similar cements. (See Part III.)

Arrises, or sharp corners of plastered walls, require to be of extra strength, or protected in some way from being chipped and injured.

Angle Staves are substantial beads or cylinders of wood plugged to the salient angles of the walls, and splayed so as to receive the plaster on each side. They thus protect the angle of the wall from injury.

Cement Angles are often formed instead of angle staves. The angle of the wall, including a strip of 4 or 6 inches wide on each side, is rendered in cement, and is consequently harder and more able to withstand a blow than if finished in plaster. The corner of the wall or of the cement covering may with advantage be rounded.

Cement Staff Beads or *Quoin-beads* are similar in form to those in wood, described at page 119, and are adopted in order to avoid an arris, and to answer the same purpose as angle staves.

Chapter X.

PAINTING. PAPERHANGING. GLAZING.

THE object of painting is to preserve the more perishable parts of a structure from the effects of the weather, heat, gases, etc.

Woodwork should only be painted when it is thoroughly seasoned; if it is not so, the paint, by confining the sap and moisture, only hastens decay.

In the best buildings the woodwork receives at least four coats of paint, sometimes five or six; but in those of an inferior class two or three coats only are used.

Each coat, as the work approaches completion, should incline more in tint to the final colour.

Materials used in Painting.—Before proceeding farther it is necessary to allude briefly to the materials of which ordinary white lead paint is composed, though the composition and peculiarities of these materials, and other points connected with the subject, will be gone into more fully in Part III.

The paint in ordinary use for protecting woodwork is composed chiefly of white lead, linseed oil, and litharge (or other "driers"); sometimes a little turpentine, and small quantities of other ingredients are added, as hereafter explained.

The part played by each of the principal ingredients is as follows:—

The linseed oil soaks into and fills up the pores of the wood, and there dries into a sort of resin, which keeps out the air, and prevents decay.

The litharge or driers quicken the hardening or drying of the oil.

The white lead gives a body to the paint, and combines with the oil to form a kind of soap.

The spirits of turpentine, or "turps," is used merely to save oil, and to make the paint more liquid, so as to work freely. It evaporates, and plays no part in protecting the wood.

Red lead is generally used with the priming coat; it dries well and sets hard.

Proportion of Ingredients of Lead Paint.—The exact proportions

for the different materials to be used in lead paint vary according to the quality of the materials, the nature of work to be done, the climate, and other considerations.

The proportions given in the following table must, therefore, be taken only as an approximate guide for inside work when the materials are of good quality :—

Coat.	White Lead.	Red Lead.	Raw Linseed Oil.	Litharge or Patent Driers.	Turps.	Number of Superficial Yards the Paint will cover.
	Lbs.	Ounces.	Pints.	Ounces.	Pints.	
1st Coat or Priming......	10	1	4	2*	0	63
2d Coat	10	0	2¼	2*	1½	100
3d, and remaining Coats	10	0	2	2*	2	113

* Or ½ oz. burnt white vitriol, and ½ oz. litharge.

The last two coats have the final colouring added in proportion to the depth of tint required; from 1 to 2 oz. of colouring matter is added for every 10 yards of surface to be painted, and the quantity of white lead is reduced in proportion.

Painting Woodwork. — *Preparation of Woodwork.* —Woodwork should be thoroughly dry before being painted. The surface should be planed clean and smooth, and free from dust. All nails should be punched in, so that their heads are driven below the surface.

Killing Knots.—The knots should then be "killed" by painting them over with "size knotting" or "patent knotting" (see Part III.) This is necessary, especially with fir and resinous woods, to prevent the turpentine in the knots from exuding through the paint.

There are several other ways of killing knots. Sometimes they are covered with fresh-slaked hot lime for about 24 hours, which is then scraped off; after which they are painted with size knotting, and if this does not kill them they are coated with red and white lead in linseed oil, and when quite dry rubbed smooth with pumice-stone.

Sometimes, after application of the lime, they are ironed with a hot iron, and then painted smooth.

In superior work the knots are cut out to a slight depth and the holes filled up with putty made of white lead, japan, and turpentine.

Sometimes the knots are covered with gold or silver leaf.

Inside Work.—*Priming.*—After "knotting" the "priming" coat is laid on. This generally contains a large proportion of red lead, which makes it set harder, and gives it the pink colour familiar to all in new work.

The object of this coat is to fill the pores of the wood before applying the colouring coats, which would otherwise be sucked up and wasted by the wood.

"Painters will sometimes for cheapness prime with clearcole or glue size instead of oil, which form a skin over the surface, without entering into the pores of the wood; it is liable to peel off, and should never be allowed unless the surface is too greasy or dirty to take oil priming."[1]

Stopping.—The surface should now be well rubbed down with fine sand-paper or pumice-stone, and all holes and cracks stopped with putty.

Second Coat.—When the priming is dry the second coat is laid on and allowed to harden. If the knots still show, they may be covered with silver leaf, gummed on with size. This, however, is seldom done in practice.

Third and Fourth Coats.—The third coat is then applied, and when it is dry and well rubbed down the finishing coat is added.

In good work each coat should be carefully rubbed down with sand-paper or pumice-stone, and well dusted, before the next coat is laid on.

Flatting.—For delicate interior work a fifth coat may be added, mixed with turpentine only, and containing no oil. This causes it to dry with an uniform flat dead surface, without gloss.

This coat must be laid on quickly, of a tint somewhat lighter than the ground colour.

It does not protect the material to which it is applied, as an ordinary coat of paint would do, for the turpentine evaporates, leaving only the pigment.

Flatted work will not last when exposed to the weather, nor will it, as a rule, stand washing; if it is required to do so, a little copal varnish must be added to it when mixing.

"Sometimes a little size, or raw oil well bleached, is added to the turps, in order to enable the paint to stand washing better, in which case it is called *bastard flatting*."[1]

Outside Work.—If the paint is to be exposed to the sun

[2] Seddon's *Builders' Work.*

boiled oil should be used, and the quantity of turps in the second coat should be reduced to about one-half that mentioned on page 216, and there should be no turps used in the remaining coats, except in winter, when a little is necessary to make the paint work freely.

Varnishing.—Varnish may be applied either to painted surfaces, or to the original surface of the wood; in the latter case it may either be plain, or stained with tints to darken the grain, or to imitate the colour of different woods.

"Varnish adds greatly to the appearance and durability of paint, but at the same time shows up the defects of broken or uneven surfaces.

"A priming coat, followed by a dark coat, such as chocolate or purple brown, and finished off with a coat of common varnish, is cheaper than and as durable as four coats of common colour, it looks better, is more rapidly executed, and stands washing well."[1]

New plaster work should be well sized with a weak solution of glue before being varnished.

Woodwork to be varnished should be very dry. The colour to be used should be ground up and dissolved with the varnish in the preliminary coats; the last coat should contain very little colour—better none at all.

The surface of woodwork should be treated with size before being varnished, to prevent it from swelling. This also fills up the pores, and causes a saving in the quantity of varnish used.

"Walls may be coloured and varnished thus:—First apply at boiling heat two coats of whiting, mixed with strong glue size; then fill up defects with mastic and water, rub smooth with pumice-stone, and cover with two coats of coloured varnish, the first coat mixed with one quarter of the required colour, the last coat with only half as much colour; the colour should be ground very fine, and the varnish should be copal varnish."[1]

Graining.—Four or five ordinary coats of paint having been applied, the last is composed of equal parts of oil and turpentine, and should approximate in tint to the final colour required, after which thin glazings of Terra de Sienna, Umber, Vandyke brown, or other required tints, are applied.

These tints may for ordinary work be ground in water, and mixed with small beer; but for oak graining a thicker substance is required, and the colour is mixed with turpentine and a little

[1] Seddon's *Builders' Work*.

turpentine varnish, and its surface, before it is dry, is scratched over (with *combs*, or with flat brushes, dipped in oil and turps), to imitate the grain of different woods. The representations of knots are produced by dexterous touches with the tips of the fingers, or with pieces of cloth, or sponge, moistened with turps. In ordinary work the surface is completed by covering it with two coats of copal varnish.

The ground and the graining colours differ with each variety of wood to be imitated—thus, for *Light Oak*, the ground would be of white-lead and stone-ochre thinned with half raw oil and half turps; the graining of raw umber and whiting thinned with half and half as above, the overgraining of Vandyke brown in water. For *Bird's-eye Maple* the ground would be of white stained with vermilion, thinned with 3 turps, 1 oil; the graining York brown, Vandyke brown, and burnt sienna, in porter, with a little paste.

A detailed description of the processes by which different kinds of wood are imitated would be of no practical use; the examples just given are merely to convey a general idea of the methods adopted.

Grained work, including the varnishing, lasts longer than ordinary painted work.

Superior work is "*overgrained*"—that is, a glaze of colour in beer, as dark as may be requisite, is laid over the comb-work in shades thrown across the work.

Painting Plaster.—Plaster to be painted should be carefully laid, and its surface free from air bubbles or flaws caused by the "blowing" of the lime.

Special care must be taken that both the plaster and the wall itself are perfectly dry before they are painted.

It is safer to distemper the walls and leave them for two years before painting. Then brush the distemper well down (without washing, unless it is greasy), and paint over it.

There are several methods of applying the paint, all of which are influenced by the very absorbent nature of the plaster.

The plaster may be primed with glue size to prevent absorption, and then four coats of ordinary lead paint applied. Care should be taken that the whole surface stands out with an equal gloss, after which it may be flatted.

The plaster may be primed with two or three coats of boiling linseed oil. When this is dry it is covered with a thin coat of

weak size, tinged with red lead, to stop all absorption, and give the work a uniform appearance, and then finished off with two coats of oil paint, and a flatting coat if required; or with two coats of coloured varnish, as described at page 218.

Another plan is to prime the plaster with white lead and linseed oil containing a little litharge, and mixed to the consistency of cream. When the oil is absorbed into the plaster, and this coat is dry, another similar coat is given. In a few days a third coat may be added, rather thicker, and containing a little turpentine. By this time, the plaster being thoroughly saturated, a fourth coat, thinned with equal parts of turps and oil, may be added, and then the flatting coat; or, when the work is not required to be very durable, the fourth coat may be omitted.

SANDING.—Fine sand is sometimes thrown on to the last coat while it is wet, with a view to imitating the rough surface of stone.

FRESCO is painting on plaster done while it is wet. It requires to be performed with great rapidity, and with care, as the work cannot be altered.

Painting Canvas and Paper.—*Canvas* to be painted should be prepared with size—oil causes it to rot.

Paper should be covered with a thin coat of oil paint, and then the other coats applied as usual.

Sometimes after the first coat of paint a coat of size is applied; but this, though cheaper, is not such good work.

Clearcole consists of white lead ground in water and mixed with size. It is useful in preparing greasy and smoky surfaces to receive paint, which is afterwards laid on in the ordinary way, the white lead being mixed in half oil half turpentine with the colouring pigment and driers, and laid on as stiff as possible.

Repainting Old Work.—The surface should be scoured with soap and water; if greasy or smoky, washed with lime water; when dry, rubbed down with sand-paper or pumice-stone; all necessary repairs should be made, cracks and openings stopped with putty, and portions from which the paint is blistered or knocked off brought up to the general level by painting, or with cement, before the surface is repainted.

When the old paint is very much blistered, it should be removed altogether before repainting.

This may be done by various solutions containing potash, quicklime, etc., which will be described in Part III.; or the old paint may be scraped or burnt off.

Painting Ironwork.—*Cast Iron* should be painted directly it leaves the mould, in order to preserve the hard skin which is formed upon the surface of the metal by the fusing of the sand in which it is cast. After this a second coat will be required, and will generally be sufficient for the preservation of the iron from atmospheric influences.

In any case all rust upon the surface of castings should be carefully removed before the paint is applied.

Wrought Iron.—Before painting wrought iron, care must be taken to remove the scales or film of oxide formed upon the surface of the iron during the process of rolling, and which, by the formation of an almost imperceptible rust, becomes detached from the iron itself.

An attempt to prevent this rusting is sometimes made by dipping the iron while still hot in oil. This plan, however, is expensive, and not very successful.

Paraffin may with advantage be substituted for the oil.

The scale is sometimes got rid of by "pickling," the iron being first dipped in dilute acid to remove the scale, and then washed in pure water. A similar process is applied to mild steel.

"If the trouble and expense were not a bar to its general adoption, this is the proper process for preparing wrought iron for paint, and it is exacted occasionally in very strict specifications.

"But somewhat the same results may be obtained by allowing the ironwork to rust, and then scraping the scale off preparatory to painting. If some rust remains upon the iron, the paint should not be applied lightly to it, but, by means of a hard brush, should be mixed with the rust."[1]

Ordinary lead paint may be used for ironwork but it is thought that the lead and iron are apt to set up a galvanic action together, which destroys the paint.

The paints made with oxide of iron (some of which will be described in Part III.) are therefore preferable for this purpose; but they must be used alone, and not laid upon a priming containing lead, or the two metals will set up a galvanic action as above described.

Bituminous paints are said to adhere better than others to the surface of the iron, and to form a plastic film which yields without cracking when the iron expands and contracts under changes of temperature.

[1] Matheson's *Works in Iron.*

All tooled surfaces in ironwork should be coated with tallow and white lead.

Gilding is of two kinds—"*burnished*" bright or left "*dead.*" The latter description is most usual in the decoration of buildings.

The painted surface is covered with "oil gold size." When this is dry but sticky, the gold leaf is laid on in narrow pieces, overlapping slightly at the edges. These are pressed down to the surface with cotton-wool, and the loose portions brushed off.

In gilding varnished work, white of egg beaten up in water is applied to those parts where the leaf is not required to stick.

When woodwork is to be gilt with burnished gold, a different size is used, called "burnished gold size." The leaf adheres to this, and when the size becomes hard the surface of the leaf is rubbed bright with a dog's-tooth or other burnisher.

In gilding ironwork the surface of the iron must be very carefully cleaned, and then painted, first with two coats of oxide paint and then two coats of lead paint of light colour. It is then ready for sizing and gilding.

PAPERHANGING.

Walls to be papered should be thoroughly dry before the paper is hung.

The surfaces of walls to be papered for the first time should be stopped, rubbed smooth with pumice-stone, and then treated with a coat of size, which prevents the plaster from absorbing the paste.

In order to obtain a smooth surface to work upon, a plain coarse white "lining" paper is sometimes hung first. In hanging lining papers the edges of adjacent pieces overlap about $\frac{1}{2}$ inch, and are distempered, and well rubbed down, to prevent their showing through the wall paper. Common papers are hung with their trimmed edges facing the light, so that they may not cast a shadow. Good papers are hung edge to edge.[1] Where the walls are damp, and battening with lath and plaster would be too expensive, canvas may be stretched tight, and nailed to battens, to receive the paper; it is, however, generally unsatisfactory, as it expands and contracts with the changes in the weather.

The heads of the nails securing the canvas should be covered over with strips of common paper before the papering is hung. Iron nails should be painted.

[1] In ceilings the edges of the paper should run at right angles to the principal light in the room.

Re-papering.—In re-papering walls the old paper should be removed, the walls scraped, washed, stopped, and coated with size; or, if the old paper is left on, a coat of size may be applied to it, and then over that a coating of whiting and size or distemper.

There is considerable danger in leaving the old paper upon the walls, and it should never be allowed, as the paste which secures it is apt to become decomposed and injurious to health.

"*Indiarubber, gutta percha, laminated lead, and tinfoil papers* 'have been used as lining papers for walls where damp would be likely to injure the paper; but all these are now superseded by the papers made by the Willesden Waterproof Paper and Canvas Company, 34 Cannon Street, London, which are much cheaper, and may even be used by themselves, being supplied in certain colours besides admitting of being coloured.' The drying of walls may be quickened by rubbing them over with sulphuric acid."[1]

GLAZING.

Glass is fitted into window-sashes made of wood or iron, or into lead work, as described at page 227.

Glazing in Wooden Sashes.—The construction of a wooden sash has been described at page 100, Chap. V., and it has been there explained that the styles and bars of the sash have rebates formed upon their inner sides to receive the edges of the panes with which they are to be glazed.

The size of the squares, and the stoutness of the sash bars, should be arranged so as to suit the kind of glass intended to be used.

The glass is cut with a diamond into panes. The dimensions of these should be a little less both ways than the distances between the sides of the rebates upon which they are to rest, so that the edges of the glass nowhere actually touch the woodwork of the sash, and any jar received by the latter is deadened by the intervening putty before it is felt by the glass.

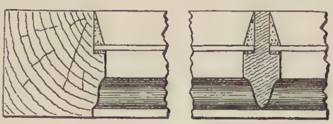


Fig. 291.

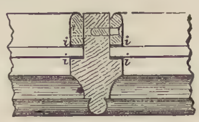


Fig. 292.

A layer of putty is spread over the narrow part of the rebates, upon which the glass is firmly bedded. This is called the *back putty;* as the glass is pressed upon it the superfluous putty is

[1] Seddon's *Builders' Work.*

squeezed out round the edges of the panes, and cut off on the inside.

This superfluous putty should not be cut off for four or five days, as its removal may disturb the front putty.

The back putty is sometimes omitted in inferior work. When plate-glass is used it is not required.

The glass is then *front-puttied,* the rebate is *stopped,* that is filled in with putty to a triangular section, as shown in Fig. 291. This soon hardens, and keeps the glass secure.

Care must be taken that the putty does not project beyond the front of the rebate, so as to be seen from the inside of the window.

Large panes of plate-glass are not back-puttied, for it would be useless in the case of large and heavy panes to attempt to compress the putty when bedding the pane.

In very large and heavy panes copper brads or *sprigs* are driven in to secure the glass more firmly before it is front-puttied, or the glass may be secured by beads or mouldings secured to the bars or frames of the sashes, as in Fig. 292.

Large panes of plate-glass in doors are sometimes bedded in wash-leather or vulcanised indiarubber, one piece glued to the inside of the rebate the other placed on the reverse side of the glass (see *i i,* Fig. 292), so as to deaden the effects of concussion.

Plate-glass is thick, and keeps a room warm, but is expensive, and therefore used only in houses of a superior class.

Firsts, seconds, and thirds sheet, or crown, glass are used in buildings of an inferior description (see Part III.)

The glazing is generally done after the plastering is finished and the floors laid, and before the painting, the sashes being primed however before the glass is put in, in order to prevent the wood from absorbing the oil out of the putty. The surfaces of all puttied joints should be painted, to prevent the oil from evaporating.

Glazing in Iron Sashes.—Iron sashes have bars of similar shape to that of wooden sash-bars, and are glazed in the same way, particular care being taken that the glass does not touch the iron, in order to avoid the risk of its being broken.

Glazing Skylights.—As already mentioned (see p. 143), skylights and other inclined sashes have no horizontal sash-bars; the panes are made to overlap, as shown in Fig. 211. When they are large and heavy, any tendency for them to slip down is prevented by hanging the tail of each on to the head of the pane

below by means of a zinc or copper *tingle*, as shown by the dark line in Fig. 211.

"Considerable overlap is necessary to prevent leakage, for the overlapping surfaces can seldom be brought into direct contact; consequently wet is held and drawn up by capillary attraction, and if the lap is not sufficient it will drip over the heads of the under sheets, and, moreover, get blown up by the wind; therefore it is better, if possible, to keep the overlapping surface far enough apart to prevent any capillary action coming into play. The tails of the panes are frequently cut to a point or rounded to throw the water off better, as well as to turn it away from the sash-bars."[1]

Glazing without Putty.

In large roofs, especially those which are subject to vibration, as in the case of railway stations, or those subject to hot fumes such as arise from some workshops, it is desirable to avoid the use of putty, which becomes dried and loose, and is shaken out so that leaks are caused in the roof.

Every good system of glazing without putty should have the following characteristics.

a. It should be simple in construction, so as to be easily repaired by ordinary workmen. Broken panes should be easily replaced.

b. It should allow of expansion and contraction of the roof (if it is of iron) under changes of temperature without breaking the glass.

c. It should be of such a structure and strength that men can easily get at any part of it for cleaning and repairs.

d. The fastenings and metal parts should be so placed as to be protected from corrosion by the weather.

e. It should not be obscured by heavy framing or sash bars, but should give a good proportion of light for the area it covers.

Of late years many systems of glazing have been introduced in which the use of putty is altogether avoided.

Of those now in use the principal forms are shown in Plate IV. The writer has had most of these forms tried. He prefers, however, not to make any invidious comparison between them. Sometimes a system not suitable for one structure is suitable for another.

[1] Seddon's *Builders' Work.*

SYSTEMS FOR GLAZING WITHOUT PUTTY.

Plate. IV.

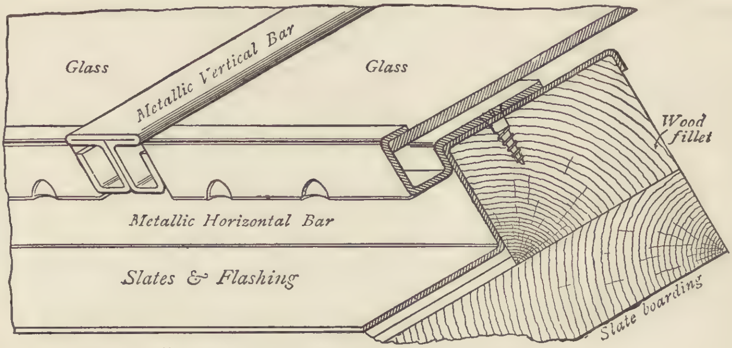
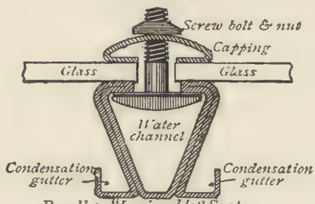


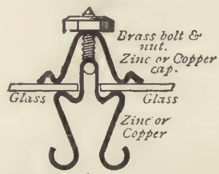
FIG. 293. *Rendle's "Acme" System for squares up to 4ft. in length.*

FIG. 294.



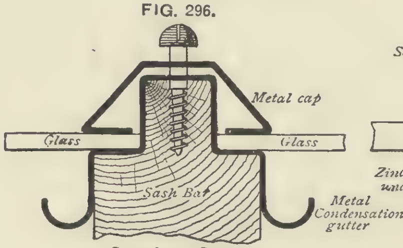
Rendle's "Invincible" System for squares up to 8ft. in length.

FIG. 295.



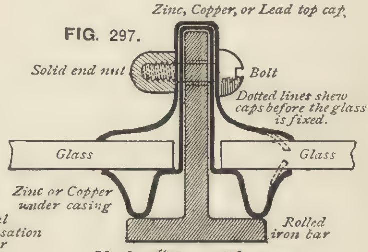
Helliwell's "Perfection" Bar.

FIG. 296.



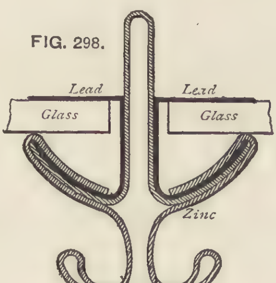
Causeley's System.

FIG. 297.



Shelley's "Unique" System.

FIG. 298.



Pennycook's System.

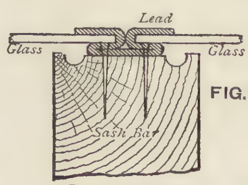


FIG. 299.

Grover's System.

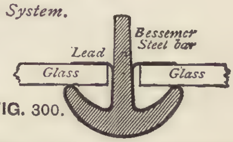


FIG. 300.

British Patent Glazing Company's System.

The student can test these forms, and many others that he will see advertised from time to time, by the list of characteristics given above, and can thus form an opinion as to which is best suited for a particular purpose.

Lead Work.

The small diamond-shaped panes used in old cottages and in churches are set in lead strips called *cames,* soldered together to form the panes.

The lead is first cast into bars, and then passed through a vice, which turns them out in cames about 6 feet long.

The section of the cames resembles the letter H. The dimensions vary according to the purpose for which the lead is intended. In the size most commonly used the sides of the H are $\frac{3}{8}$ inch long, the cross-bar between the sides $\frac{3}{16}$ inch long, and the thickness of the metal about $\frac{1}{48}$ inch.

The sides of the cames are bent down so as to admit the panes, and then turned up again, so as to form a groove in which the edges of the panes are secured.

In large windows the leadwork is strengthened by iron *saddle-bars,* to which the cames are secured either by leaden *bands* or with copper wire soldered to the cames and twisted round the iron. The saddle-bars themselves are supported, when necessary, by iron *stay-bars,* or *standards,* which are fixed in the masonry.

Fretwork is somewhat similar to the leadwork just described, but that the cames are of much lighter section, and instead of being in regular shapes, such as squares and diamonds, the pieces of glass are cut so as to form figures or other patterns, and the cames are bent round to fit the edges of the pieces.

CHAPTER XI.

HEATING AND VENTILATING BUILDINGS.

IN dealing with this subject, it will only be possible, on account of the limited space that can be afforded it, to touch superficially on the chief points which must be considered in selecting and designing heating and ventilating apparatus.

The theory of heating and ventilating is in itself a very wide subject, embracing as it does so many of the physical sciences; and it is therefore intended to pass briefly over questions of theory, and to turn rather to the description of the various methods in use in common practice.

There is a development going on at the present time, which is in itself a good sign, and which promises to improve the sanitary conditions under which we live. Until quite recently the heating of a building was carried out by one engineer, and the ventilating by another. There was no connection whatever between the two installations, and consequently the result was generally a failure. We are now beginning to realise that they cannot be treated separately; but that they are both parts of one whole, which must be taken together to ensure a satisfactory result.

One of the results of this is, that architects are seeking the assistance of a consulting engineer, to prepare for them a proper scheme, and to make out a plan and specification, on which the competing contractors can base their estimate. In doing so, they are undoubtedly taking a very wise step. There is nothing that has been responsible for more failure in heating and ventilating than the fact of leaving each of the contractors to prepare a scheme of his own. The knowledge that the lowest tender will probably be accepted prompts them to cut down the heating surface, size of mains, and boiler power; and when the work is done it is found to be inefficient. Although it is usual to guard against this, by

obtaining a guarantee of the temperatures at which the various rooms are to be maintained, yet nothing is more difficult than to bind a contractor to a guarantee. The part of a room which is nearest to the source of heat is invariably warmer than that which is more remote; and now that radiators have been almost universally adopted for heating surface—and there are many reasons which make them the most suitable form of heating surface—the thermometer readings generally show a considerable difference of temperature in the different parts of a room. It is consequently a difficult matter to decide if the contractor has done what can reasonably be expected of him.

When an architect is unable to call in the assistance of an engineer he should state what internal temperature it is desired to maintain, with a given external temperature. He should always require of each contractor (1) a full description of the boiler, clearly stating the amount of surface it is capable of heating; (2) the exact amount of heating surface that has been provided in each room to be heated; (3) the amount of air provided for ventilation; and (4) the means by which the air is to be admitted into and discharged from the building. From these particulars, it is a simple matter to see what each contractor is quoting for, and to form some opinion, by comparing the heating surfaces, as to the probable results which will be obtained. It is also advisable, before placing the order for the work, to ask the contractor by what means he arrived at the heating surfaces; and if this has been done in a proper and scientific way, the contractor will generally be willing to explain his method, in order to gain the confidence of the architect and so secure the work.

Of the many forms of heating apparatus the most common is the open fireplace. It has two points in its favour: it is pleasant to look at, and it lends valuable aid in ventilation. But it is a very extravagant means of heating, as not more than 10 to 15 per cent of the heat units in the consumed fuel are utilised for warming purposes, even in the most improved forms of fireplaces, while the rest are carried off by convection up the chimney.

The open fireplace was improved many years ago by the invention of a form known as the Galton grate. In this, a chamber was built at the back of the fire, and connected with the outer air. By contact with the heated plates surrounding the fire the air in the chamber became heated, and its specific gravity being reduced, it rose up a fresh-air flue, which was provided, and dis-

charged itself into the room near the ceiling level. As air was at the same time being extracted from the room by the chimney, near the floor level, there was, no doubt, a very complete circulation set up. The appearance of the grate made it unsuitable for a well-designed and decorated apartment; but for barrack-rooms and dormitories it was found to be, and still is, a very useful form of apparatus.

The heating stove is a more efficient means of warming, and there are many forms which, on the same principle as described in reference to the Galton grate, deliver warmed fresh air to the apartment; but they are unsightly, they take up useful room, and can only be used with advantage in special cases. They render the air very hot and dry, an objection which can be overcome by placing an open vessel of water upon them; and they occasionally emit a bad smell, by decomposing the organic matter in the air which comes in contact with the highly heated surfaces. Moreover, in the case of cast-iron stoves, carbon monoxide is diffused through the heated plates.

Whenever a building is warmed by several small fires, it may be accepted as a fact that a very great waste of fuel must result. A much more economical arrangement is to have one central furnace from which the heat can be delivered to the various parts of the building.

This is secured in several forms of hot-water and steam-heating apparatus.

The usual systems of hot-water warming are:—

(1) The low-pressure system.
(2) The closed-tank or drop system.
(3) The high-pressure system.

The low-pressure system is the one in most general use, and is highly efficient, if properly designed. If sufficient heating surface is provided within the boiler, and a proper flue area, proportionate to the grate-bar area, is provided, the waste heat is reduced to a minimum. A contracted heating surface in the boiler will cause a higher temperature in the chimney, and a greater loss of heat by convection. Badly proportioned flues will cause too rapid or incomplete combustion of the fuel.

The apparatus consists of a boiler, flow and return main pipes, and radiating surface.

The boiler is fixed at the lowest point; from the top of the boiler the flow main pipe is carried, rising throughout its entire

length, to the radiating surface. The return main is brought back from the radiating surface, falling throughout its entire length, until it is connected into the bottom of the boiler. On lighting the fire in the boiler, the temperature of the water in the flow main is raised, and its specific gravity consequently falls below that of the water in the return main, which has not been affected by the heat of the fire. Equilibrium being thus upset, the water in the flow main rises, while that in the return main falls. The heated water from the flow main now enters the radiating surface, and here gives out its heat, by radiation, to the apartment which is to be warmed. It therefore becomes heavier than the water in the flow main, and falls through the return main back to the boiler. By the continual repetition of this process the circulation is set up. The motive force which produces this circulation is the difference of weight of the water in the flow and return pipes.

The above is the simplest form of apparatus. In actual practice there are frequently several flow and return mains, with several branches leading from them, but the same principles apply and a circulation is set up in each main, a tendency for one main to take precedence over the others being regulated by valves placed in the various mains.

At the highest point in this system is a tank, which is open to the atmosphere. This tank is provided for the expansion which takes place in bulk of the water when it is heated. Its cubic contents are therefore proportionate to the volume of water in the apparatus, and the number of degrees through which it is heated. It is also a convenient place at which to lay on the supply to the apparatus; the service being brought to the tank, terminating in a ball valve. The supply is usually carried from the tank, to one of the return main pipes, as near the boiler as possible.

An air-tap must be provided at any point in which air is likely to collect, such as at the top of all radiators and the syphon ends of runs of piping. If the air is not allowed to escape, it quickly forms a large air bubble which effectively cuts off the circulation of the water.

The second method is a slight modification of the above apparatus. In this case, instead of an open cistern, a closed tank is fixed at the highest point, and provided with a relief valve for releasing the pressure when it becomes too great. It may be

called the "medium-pressure system." It is constructed in very much the same manner as the low-pressure apparatus. The advantage of having the closed tank is, that the temperature of the water can be raised above the ordinary boiling-point, so reducing the amount of radiating surface necessary. The boiler is placed at the lowest point, and the main flow and return pipes are carried to and from the tank, but the branches are carried round the top of the building, with drop mains to the bottom of the building. The radiating surfaces are usually connected to

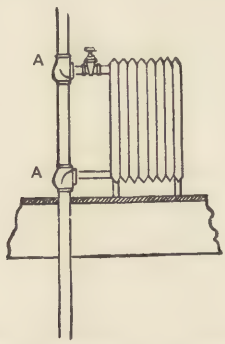


Fig. 301. Connection of Radiator to Drop Main. Distributing Fittings at points marked A.

Fig. 302. Section of Distributing Fitting.

these drop mains, as shown in Fig. 301. The branch tee, which is called a distributing fitting, is shown in section in Fig. 302.

The circulation is somewhat quicker in this system, and the main pipes can be of rather smaller diameter than for the low-pressure system.

The third method of hot-water heating is called the high-pressure system. In this the heating surface, mains, and radiating surface are formed of an endless pipe of very stout wrought iron, generally of about $\frac{7}{8}''$ internal, and $1\frac{5}{16}''$ external diameter; but sometimes $1''$ pipes are used for portions of the apparatus.

The ends of the tubes are cut with right and left hand threads, the former being faced, and the latter coned. The socket for connecting them is also cut with right and left hand threads, and, upon screwing up, the cone end is forced into the faced end, and thus forms, without any packing, a perfectly sound metallic joint. An illustration of this joint is shown in Fig. 303.

The lower portion of the endless tube is made into a coil, inside the furnace, which is either of wrought iron or brick-work, the latter

method being adopted where more than 1800 or 2000 feet of piping is to be heated. The return pipe near the boiler is sometimes coiled and placed in the flue.

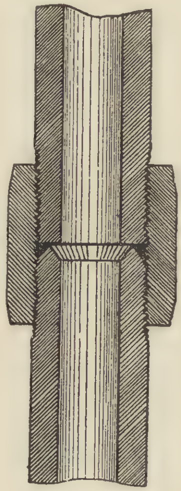


Fig. 303.
High-pressure Joint.

The boiler is placed at the lowest point of the apparatus, and although dips are not so detrimental to the effective working of the apparatus as in the low-pressure system, it is well to avoid them if possible.

In filling the apparatus care must be taken to entirely free the pipes from air.

The apparatus is filled by pumping in water at a point near the boiler marked A in Fig. 304; pumping is continued until the water escapes from the pipe B, which is fixed above the highest point of the circulation. A cap is screwed on at B and the apparatus tested; as the test is carried out when the pipes are cold, it is necessary to subject them to a pressure varying from 1500 lbs. to 3000 lbs. per square inch, depending upon the temperature required. This is done because, although when working the pressure is much lower (on an average 500 lbs. per square inch), the pipes when hot have their strength considerably lessened, especially in the case of the boiler coil.

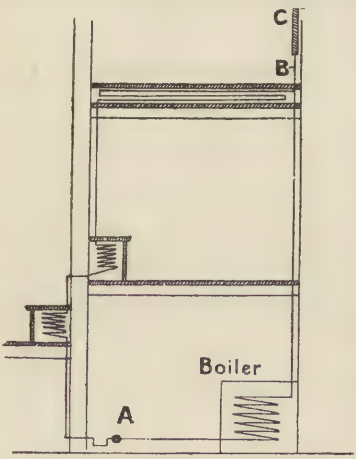


Fig. 304. Single Circulation.

At the highest point in the apparatus an expansion tube C is fixed (Fig. 304). It varies in diameter from 2 to 6 inches, depending on the amount of water in the pipes. When the apparatus is filled in the first place, the tube C only should contain air. As the water expands when the apparatus is working, it forces its way into this tube, and cushions against the air contained therein. The compressibility of this air prevents bursting, which would be inevitable were the apparatus quite full of water.

In public buildings or ordinary dwellings, where moderate

temperatures are required, a relief valve is more frequently used than an expansion tube. A sketch of this valve is given in Fig. 305. The valve is immersed in a cistern of water, and when the pressure becomes too high, the valve opens and releases some of the water, thus reducing the pressure. On the other hand, when the water gets cooler in the apparatus, the resulting

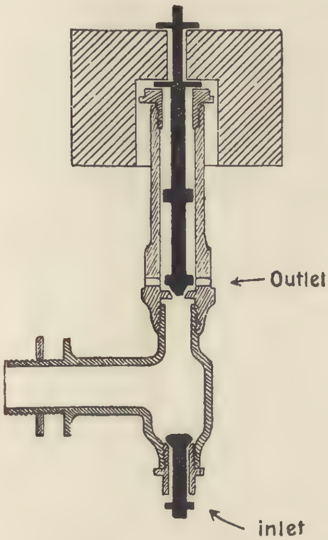


Fig. 305. Relief Valve.

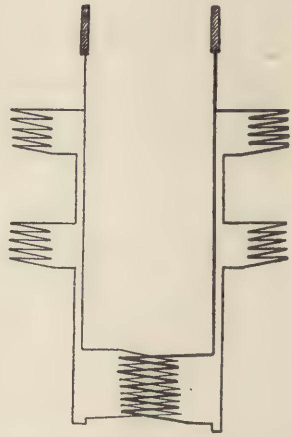


Fig. 306. Duplicate Circulation.

vacuum causes water to rush in through the inlet portion of the valve.

In the high-pressure system the circulation may be arranged in four ways, viz. :—

(1) The single circulation (Fig. 304), in which the boiler coil and radiating pipes are practically one long tube.

(2) The duplicate circulation (Fig. 306), having more than one complete single circulation, the boiler coils being in the same furnace.

(3) The branch circulation (Fig. 307), in which branches are taken off from different points in the flow mains, and rejoined to different points in the return mains. The object here is to allow various portions of the circuit to be cut off without interfering with the remainder; and also to shorten the circuits and so get the water back to the boiler more quickly. The various circuits

would have to be supplied with valves to prevent one taking the lead to the detriment of the other.

(4) Crossed circulation (Fig. 308). This arrangement is perhaps the best, where a large amount of piping is used. Take, for instance, an apparatus in which there is a length of 3000 ft. of pipe. This would be arranged in six cross circuits, each working about 500 ft. It will be easily seen that this is much better than having one long circuit; for owing to the smallness of the pipe the heat is radiated long before the water gets back

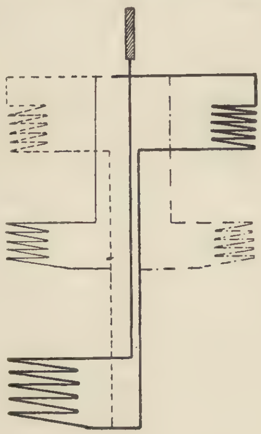


Fig. 307. Branch Circulation.

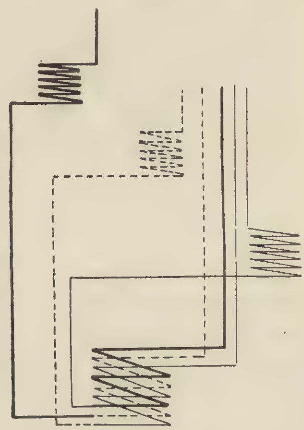


Fig. 308. Crossed Circulation.

to the boiler, thus rendering a portion of the piping almost useless for heating purposes.

Where high temperatures are required this system is very useful; but for ordinary warming purposes for buildings or dwellings it cannot be recommended, because the air is rendered undesirable for breathing by contact with the highly heated surfaces of the pipes.

The systems of steam heating are known as (1) the high-pressure system, and (2) the low-pressure or gravity circulation system. In the former, live steam of any pressure is provided in the boiler, and conveyed in the main steam pipe to the radiating surface, the condense being discharged through steam traps and pumped back into the boiler. This method of heating is only employed where steam is required for engines or some other purpose. With high-pressure steam, radiators are not used. The radiating surface generally consists of coils of wrought-iron

pipes. At any point where condensed water can accumulate, a steam trap must be fixed. (A steam trap is an automatic appliance. It discharges the condensed water, which can then be drained back into the hot well or sump and pumped again into the boilers.)

In the low-pressure or gravity circulating system, the steam is usually produced in a cast-iron boiler, used only for warming purposes. The pressure is limited to 7 or 8 lbs. per square inch, and cast-iron radiators are used for the radiating surface. The steam is conveyed to the radiators in the steam main, and the condensed water is returned to the boiler in the condense main. In erecting an apparatus it is of the greatest importance to arrange the main pipes in such a manner that the flow of the steam and the condensed water shall always be in the same direction. Steam mains are never fixed quite horizontally. A slight inclination must be given the pipes so that the condensed water cannot stand in the pipes. This inclination is called the pitch. The steam main is generally taken vertically from the boiler to its highest point, and from there the horizontal distance is covered with a slightly falling pitch. When the horizontal distance is great, it is sometimes necessary to form what are called relays in the steam main. These are points where the pipe has to be carried vertically upward for a foot or two, so that the pitch for the next section of the main may still be downwards. Wherever a relay occurs, it is necessary to provide what is called a drip pipe, which is carried from the bottom of the relay into the return or condense main. This prevents condensed water from accumulating in the steam main, and so causing what is known as water-hammer. Drip pipes must be provided at all points where water can accumulate. The return or condense main must be inclined downwards from its farthest point to the boiler. All valves used in steam heating should be full way. Globe valves should not be used, because in the latter the seating, on which the valve shuts down, is considerably above the bottom of the pipe, and thus forms an obstruction which holds up condensed water. At all points where air can lodge, automatic air valves must be provided. These valves have a sensitive plug which allows air to pass out, but when the steam comes in contact with

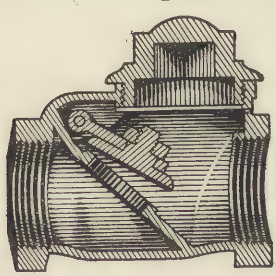


Fig. 309.
Back-pressure Valve.

it, it expands with the heat of the steam and so closes the valve. A back-pressure valve (Fig. 309) must also be provided in the condense main near the boiler. This valve prevents the pressure in the boiler from being transmitted up the condense main.

Exhaust steam from engines can often be economically used for warming purposes. As near as possible to the engine, the exhaust steam is taken into what is called a heater or calorifier. This is a strong cast-iron receptacle usually in the form of a cylinder. It contains a battery of copper pipes through which the exhaust steam passes. Surrounding the copper pipes is a space containing the water used for heating. The exhaust steam on entering the calorifier quickly condenses by imparting its heat to the water. In doing so it tends to form a vacuum, and so takes pressure off the engine. The condense is carried into the sump and pumped back into the boiler. When this method of heating is adopted, the calorifier takes the place of the heating boiler, and the flow and return main pipes are carried from it in exactly the same way as described in the low-pressure water-warming system.

Live steam is often utilised for warming in the same manner.

In all the above systems the warming is effected by what is called "direct heating," that is, the radiating surface is fixed inside the apartment which it is required to warm.

There is another method, known as "indirect or air heating." In this the warming is effected by heating the air outside and discharging it into various apartments through air-ducts. In other words, the ventilation of the building becomes a part of the scheme.

The efficiency of an indirect heating apparatus depends upon the means provided for the introduction of the fresh warmed air, and the carrying away of the vitiated air from the building. This may be done by what is called natural ventilation, or mechanical ventilation.

In all movement of air, work is being performed by some force, and in natural ventilation it is the force of gravity. It operates upon the difference in the specific gravity of the air inside the building, which is heated, and that outside the building, which is not heated. The greater the difference between the internal and external temperature, and consequently the specific gravity of the internal and external air, the more rapid is the change of air. The nearer the internal and external temperatures approach, the less rapid becomes the change.

In the latter case the conditions are very unfavourable for the efficient working of all natural ventilation systems; and as it sometimes happens that ventilation is needed most just when the conditions are least favourable, such a system cannot be relied upon to fulfil what is required of it. The principle of heating the air at the base of the extraction flues will certainly in some measure overcome the difficulty, but it is obviously a very wasteful method, and cannot be recommended on the grounds of economy. Neither will the fixing of large cowls, or extract ventilators, on the top of these flues ensure the movement of the large volume of air which is necessary, for they depend in their operation upon the movement of the external air. It is true that a strong wind passing across the opening at the top of a flue does produce considerable aspirating effect, but when the air is calm this aspiration is reduced to a minimum.

The best form of indirect heating, which comes under the heading of natural ventilation, is the hot-air furnace. The furnace is placed in the basement of the house, and is encased in an air-chamber, formed either in brick-work or metal casing. The supply of air is brought to the bottom of this chamber in a main flue from the outside air, and so arranged that in entering, it impinges upon the heated surfaces of the furnace. From the top of the air-chamber flues are taken to the various rooms. All horizontal runs of these flues should be circular, because a circular pipe offers less surface for friction than a rectangular pipe of equal area. The vertical portions, or stacks, are usually made rectangular, for convenience in fixing in the walls and partitions of the building. Escape flues must be provided in each room, otherwise the circulation of the air will be very uncertain. The force which causes the circulation, being, as before described, the difference in the weight of the heated air in the flues and the colder air outside, is very small. Consequently the horizontal distance (where the greatest frictional resistance occurs) which the air will travel is short, and on account of this, furnace heating is not suitable for buildings of large extent. But for a small building, such as an ordinary residence, a well-designed apparatus will give good results.

There is another system in which natural ventilation can be made to work well. This is a combination of direct with indirect heating. In this system a hot-water or steam-heating apparatus is fixed, as before described, with radiators for the radiating sur-

face. These radiators are connected directly with the outside air. By this means fresh air can be drawn in, being warmed by contact with the heated surfaces of the radiators, and discharged into the building. Provision must be made for the out-going air, and if this is done by means of a fan, it can no longer be called natural, but mechanical ventilation. With the addition of the fan this system becomes a highly satisfactory one, and can be adopted with advantage in almost any class of building.

There are two other systems of combined heating and mechanical ventilation. They are both operated by means of a fan, or blower. In the first, the air is drawn in by the fan, and blown over the heating surface, which is usually heated by steam, and conducted in flues to the various rooms to be heated. In connection with the fan a cold-air flue is also carried beside the hot-air flue. These flues are united before the air enters the rooms, and by means of regulating-valves the temperature of the room can be controlled. The valves are so arranged that when one is opening the other is closing, so that the mixture of the heated and cold air can be regulated.

In the second system, the heating surface is not concentrated at one point, but is divided up and fixed at the bases of the various upright flues, or stacks. In this arrangement of heating surface, only one air-duct is required from the fan to each heater, a bye-pass being provided at each heater. By the same arrangement of valves the air may be made to pass through the heater, or the bye-pass, in whatever proportion desired.

In both the above systems it is usual to pass all the air, before it reaches the fan, over what is called a tempering coil. This coil is usually designed of sufficient size to heat all the entering air to a moderate temperature, so that there is no possibility of any very cold air being discharged into the rooms in cold weather.

The fan or blower is generally fixed in the basement of the building, and can be operated either by running a counter shaft from an engine (which may be directly connected, or connected by belting), or by an electric or water motor. It can be most economically driven by a steam-engine, so arranged that the steam after passing through the engine is used in the heating coils. This method is the cheapest for a large installation, because only a small percentage of the heating power of the steam is lost in operating the engine, and the cost of the motive

power is thus reduced to a minimum. When the fan is only occasionally required, it is generally most convenient to run it by an electric motor.

These two systems of heating and ventilating can also be worked by exhausting fans, on what is known as the Extractum System. But in this case there is always a danger of air leaking in, which does not pass over the heating surfaces, so interfering with its proper working.

As a general rule it may be accepted that a system of mechanical ventilation is more economical and reliable than one which depends upon heated flues. The air can also be filtered, and in dry weather moistened by passing it through sprays of water; and although the cost of installing the apparatus is of necessity large, when one takes into consideration the amount of mechanical work done in heating and ventilating, the reliability of a well-designed system, and the importance of the result, it cannot be doubted that it is money well spent.

It may here be appropriate, in considering the amount of fresh air required for ventilation, to refer briefly to the theoretical side of the question.

Air is a mixture of nitrogen, oxygen, and carbonic acid in about the following proportions: nitrogen, 79·04; oxygen, 20·92; carbonic acid, ·04. It also contains watery vapour, ammonia, and various impurities, such as road dust, vegetable matter, mineral matter, exhalations from the human body, human hair, bacteria, and fibrous matter. About 1 per cent of what was thought to be nitrogen was recently found to be a gas, previously unknown. It was named argon by Lord Rayleigh and Professor Ramsay, who discovered it.

Nitrogen, which forms the largest constituent of the air, is probably a diluent of the oxygen, reducing its strength and the rapidity of its action. It is essential to all forms of life. It is also thought to supply all vegetation with nourishment.

Oxygen is the most important element in the air. It is necessary to all forms of life. It is continually being used up in the respiration of all animal life, and in combustion.

Carbonic acid is a combination of carbon and oxygen—one part of carbon uniting with two parts of oxygen. Under the influence of sunlight it is breathed in by plants, which retain the carbon and set free the oxygen. It is also given out in combustion, and by men and animals in respiration.

Wherever men congregate in an enclosed space, the proportion of carbonic acid in the air quickly rises.

Carbonic acid exists in pure air to the extent of ·04 parts per cent. Whatever amount there happens to be above that proportion must be looked upon as an impurity.

The object of ventilation is to maintain the air as far as possible in the proportions given above. There is no practical means of purifying the air within a building; therefore it is necessary to induce fresh air to enter it. But as this in-coming air contains already its proportion of carbonic acid, it is obvious that whatever quantity enters, the resulting mixture must contain a greater proportion than ·04 parts per cent. Recognising this fact, it has been generally agreed that if the mixture does not contain more than ·06 parts per cent of carbonic acid, the hygienic condition is as good as can be reasonably maintained. The proportion of ·06 parts of carbonic acid per cent is called the maximum limit of impurity.

The ill-effects of impure atmosphere are not entirely due to the excess of carbonic acid. Organic matter, impurities given off from the skin and lungs of human beings, and also the reduction of the oxygen, are contributory causes. But carbonic acid is a gas of which the quantity can be accurately measured, and it has been found that by limiting it to ·06 parts per cent, the other impurities are also limited to an extent which renders them comparatively harmless.

As has already been stated, carbonic acid is given off in combustion. Therefore all illumination which is due to combustion adds to the amount of carbonic acid in the air. This must be taken into account in considering the problem of ventilation.

The most common illuminants are coal-gas, oil, and candles. Less common, but much more hygienic, are the incandescent electric lamp and the arc electric light. Neither of these are due to direct combustion within the room they illuminate. The former is produced by the passing of an electric current through a very fine thread of carbon or platinum, which is thereby rendered incandescent. The thread being enclosed in a hermetically sealed glass globe, is entirely cut off from the surrounding air, and is consequently unable in any way to vitiate it. The arc lamp is not enclosed, and although it is said to vitiate the air to some extent by the formation of nitric acid, its effect is much less harmful than gas, oil, or candles.

The unit of light adopted in this country is a sperm candle of the size called "sixes"; it burns 120 grains per hour, and gives a light which is known as "one candle-power." A candle of this size yields ·41 cubic feet of carbonic acid per hour.

Paraffin oil, on account of its high illuminating power and comparative cheapness, is most generally used for lamps. When burnt in a good lamp, the consumption of about 62 grains per hour gives a light equal to one candle-power, and produces ·28 cubic feet of carbonic acid.

Coal-gas, burnt in an ordinary No. 4 or 5 fish-tail burner, gives a light of about 16 candle-power, and burns 4 or 5 cubic feet per hour; one cubic foot gives off about ·52 cubic feet of carbonic acid, or about ·13 cubic feet per candle-power.

The amount of carbonic acid given out per candle-power of these three is therefore as follows:—

Candle	·41	cubic feet	of carbonic	acid.
Oil lamp	·28	,,	,,	,,
Gas (in ordinary burner) . . .	·13	,,	,,	,,

Illuminating by candles therefore is more harmful than by lamps, which is, in turn, more harmful than illuminating by gas. But it must be borne in mind that where candles or lamps are used, we are generally satisfied with a much lower degree of illumination than when gas is used. For instance, in an ordinary small room we should require at least 16 candle-power gas illumination, whereas, if candles were used, one or two candle-power placed in a position where the light falls upon the work or book we are using is generally deemed sufficient.

It may therefore be accepted that in gas illumination the greatest amount of carbonic acid is given off; and it is customary to provide for about 500 cubic feet of fresh air for each cubic foot of gas burnt. This is not so great as the amount of fresh air which would be required for the same quantity of carbonic acid given off by respiration. But where respiration is concerned there are also the impure exhalations from the lungs and skin to be taken into consideration.

In the incandescent gas light, the illumination is obtained on a more scientific principle. Here an ordinary Bunsen, or atmospheric burner is used. The air unites with the gas, and the combustion is more complete. Less unburnt particles of carbon escape, and by rendering a gauze asbestos mantle incandescent, a higher illuminating power per cubic foot of gas is obtained, and

consequently fewer cubic feet are required. But for each cubic foot it is advisable to allow for the same amount of fresh air as in the ordinary gas burner.

The following table gives the amount of fresh air required per hour for ventilation, for various kinds of illumination :—

For each candle	400 cubic feet
For ,, lamp	1500 ,, ,,
For ,, cubic foot of gas	500 ,, ,,
For ,, incandescent electric lamp . . .	Nil.
For arc electric	Nil.

The next point to be considered is the amount of fresh air required per person. Here again sufficient fresh air must be provided to dilute the air to such an extent that the amount of carbonic acid it contains shall not exceed ·06 parts per cent. It is therefore necessary to find out how much carbonic acid is given out per person.

In the article on "Respiration" in the *Encyclopædia Britannica* the following breathing table is given :—

		Entering Air.	Respired Gases.
Oxygen . .	per cent of volume . .	20·84 to 20·92	16·03
Nitrogen .	,, ,, . .	79·00 to 79·05	79·02
CO_2. . .	,, ,, . .	0·04	3·3 to 5·5

The most important fact to notice in this table is that the carbonic acid is increased in quantity very considerably.

Physiologists state that in each respiration an adult male requires 20 cubic inches of air, and that from 16 to 24 respirations take place per minute: so from 320 to 480 cubic inches of air are required per minute.

Taking the greater amount, an adult breathes in and exhales 28,800 cubic inches per hour. But by the above table about 4 per cent of this will be carbonic acid. So each adult male will exhale 1152 cubic inches or ·66 cubic feet of carbonic acid per hour.

Now the air supplied for ventilation may be assumed to contain ·04 per cent or ·4 cubic feet per 1000. The maximum permissible impurity being ·6 per 1000, each in-coming thousand feet of air can take up ·2 cubic feet of carbonic acid. Therefore the total amount of air required for each adult will be $\frac{\cdot 66}{\cdot 2} = 3{\cdot}3$ thousand, or 3300 cubic feet.

Under the influence of hard manual work, respiration is quickened, and it has been estimated that a male doing very

hard work, such as would occur in a gymnasium, gives off 1·96 cubic feet of carbonic acid per hour. When employed on manual labour, as in workshops, ·95 cubic feet per hour.

A female at rest gives out ·60 cubic feet per hour, and a child ·40 cubic feet per hour.

From the above details, the following table has been compiled, each case being worked out in the same way as the example given:—

	Number of cubic feet fresh air required per hour per head.
Adult male, very hard at work	9800
,, ,, ordinary manual work	4750
,, ,, at rest	3300
,, female ,, ...	3000
Children ,, ...	2000
Average mixed community at rest, say	3000
Average mixed community at rest occupying a building for short periods, such as a theatre	1500

In the case of hospitals, a larger amount of air is considered necessary, because the exhalations from those suffering from disease are obviously of a more dangerous nature. It is usual to allow at least 25 per cent more air per head; and in wards for highly infectious and contagious diseases an even greater amount is essential.

It is very rare in actual practice that the full amount of air that is necessary is supplied. But it should be the object of every architect to secure this amount if possible. The chief difficulty lies in the cost entailed in moving such a large volume of air. Although our views on the sanitary question are no doubt widening, they have not yet reached that stage when what is now considered as desirable will be regarded as essential. But no doubt that time will come when a higher proportion of the cost of a building will be devoted to the warming and ventilation.

Looking at the question from the commercial side, it is well to point out that ventilation cannot be regarded as solely a sanitary precaution, taken for the benefit of the occupants of a building. In a factory, the provision of an adequate supply of fresh air has a direct influence upon the vitality of the work-people employed. Without it a feeling of lassitude is sure to be experienced, and the amount of work performed is undoubtedly smaller. This fact is well recognised in America, where well-lighted and well-ventilated shops add so materially to the prosperity of the great commercial enterprises of the country.

In erecting a ventilating apparatus, one of the most difficult things to decide is, at what points the fresh air shall be introduced and the vitiated air be extracted from the building, and a considerable difference of opinion upon this subject is found to exist. For an ordinary dwelling-room, it is obvious that the in-coming air must not be permitted to impinge directly upon the occupants. If it is introduced above head-level and in an upward direction it will not do so. In this case it would appear advisable that the outlets for the vitiated air be not placed above head-level. If they are, the fresh in-coming air will probably travel directly to the outlets, without benefiting the condition of the atmosphere of the room. It is therefore a question for consideration whether the outlets should not be placed at a lower level than the inlets; and if they are near the ground-level, and immediately underneath the inlets, it would seem probable, and it has in fact been found by actual experiment, that the air will be most effectively changed. This is certainly the best arrangement when the in-coming air has been warmed, as it always must be during cold weather. And even in the summer time, when the in-coming air is at a lower temperature than the air near the ceiling in the room, it will slowly fall on account of its higher specific gravity, and will so traverse the space in which the actual breathing is going on. It is generally assumed that the breath expired from the lungs rises vertically upwards to the ceiling of the room: and on this assumption the theory of what is called "upward ventilation," is based. It is argued that as the expired air rises above head level, if the outlets are placed below head level, it will be drawn down again, and so be re-inhaled.

If the expired air does rise up, as is assumed, it would certainly seem that the reasoning is good. But a close investigation of the actual destination of that expired air appears to throw some doubt upon this conclusion.

Let us take the case of 100 volumes of air, each weighing 1 lb.

Assuming it to be fresh air, it consists of the following parts:—

	Per cent of volume.
Oxygen	20·92
Nitrogen	79·04
Carbonic Acid	·04
	100·00

By multiplying these parts by their specific gravities the total

weight of the air is found to be very nearly accurate, as is shown below :—

	Volumes.		Relative Specific Gravity (Air = 1).		Weight in lbs.
Oxygen	20·92	×	1·10563	=	23·12977
Nitrogen	79·04	×	·97137	=	76·77708
Carbonic Acid . . .	·04	×	1·52901	=	0·06116
	100·00		Total	.	99·96801

Referring to the table on breathing, the expired air consists of the following parts :—

	Per cent of volume.
Oxygen	16·03
Nitrogen	79·02
Carbonic Acid . . . . (say)	4·95
	100·00

Again multiplying these parts by their specific gravities, we find the weight has increased by more than 2 lbs.

	Volumes.		Relative Specific Gravity (Air = 1).		Weight in lbs.
Oxygen	16·03	×	1·10563	=	17·723248
Nitrogen	79·02	×	·97137	=	76·757657
Carbonic Acid . . .	4·95	×	1·52901	=	7·568599
	100·00		Total weight		102·049504

Therefore, without for the present taking into consideration the aqueous vapour or the increase in volume, due to the increase in temperature, we find the expired air is slightly heavier than the inspired air.

We must now consider the increase in volume.

At an atmospheric pressure of 30 inches of mercury, and at a temperature of 62° F., 13·14 cubic feet of dry air weigh 1 lb.

By the law of Charles, a gas increases $\frac{1}{491}$ of its volume for each degree F. of temperature through which it is raised. Therefore if the temperature of 100 lbs. or 1314 cubic feet of air be raised from 62° F. through a range of 34° to 96° F. (the average temperature of expired air) its volume will be increased $\frac{1314 \times 34}{491} = 91$ cubic feet nearly, and will consequently become $1314 + 91 = 1405$ cubic feet.

This then is the amount of cubic space our 100 volumes of air will occupy on being exhaled; in other words, this is the amount of air which it will displace. Now the temperature of

this displaced air is 62° F., and its weight will be $\frac{1405}{13 \cdot 14} = 107$ lbs. nearly.

But it has already been shown that the weight of the expired air is only 102·049 lbs.; therefore so long as its temperature is 96° F. it will tend to rise.

But the question of importance to consider is this: Will it retain its temperature? Careful consideration seems to show that it will not. Imagine for a moment a drop of warmed water being suddenly discharged into a tank of cold water, near the bottom: does it not seem probable that long before it has risen to the top of the tank the excess of temperature that tends to raise it will be imparted to the surrounding water?

The relation of the 20 cubic inches of expired air to the cubic contents of an average room may be fairly compared to a drop of water in a large tank. The force which tends to raise it will be but $\frac{1}{172800}$ lbs.; and when we consider in what a short space of time the temperature of the air in our lungs is raised to nearly the temperature of our bodies, it seems only reasonable to suppose that in as short a time its temperature will be lowered again, when it is expired. And when we remember that we breathe out through the nostrils, in a downward direction, in two attenuated streams, which immediately baffle against the cooler air, it leaves little room for doubt that there are good grounds for the supposition. But as soon as the temperature of the expired air is lowered to that of the surrounding air, then its superior weight, due to its being a heavier mixture, will come into play and it will consequently begin to fall.

But there is one other point which must also be considered. In the preceding calculation aqueous vapour has not been taken into account, although there is a considerable quantity in the air: the quantity inhaled varies with the humidity of the atmosphere: the quantity exhaled is the amount which completely saturates the expired air. Aqueous vapour is lighter than air. The specific gravity of air being 1, that of vapour is ·6225. The presence of this additional vapour further increases the volume of the expired air, and consequently tends to lower its specific gravity. But as it is only because the temperature of the air is raised while in contact with the lungs that it is able to pick up this additional vapour, so inevitably must the vapour be given up

when the temperature falls. Again, in the foregoing argument the surrounding air has been assumed as perfectly dry, whereas the more usual condition would be one of partial saturation, implying a slightly lower specific gravity.

If therefore the above reasoning is correct, it would seem that the expired breath first has a tendency to rise, on account of its higher temperature, but directly its temperature falls again the expired air has a tendency to fall.[1] It must further be remembered that the impurities of expired air are not wholly gaseous, but include particles of matter, organic or inorganic, which are held in suspension.

But in spite of what is above stated, it is always found that the temperature of the air near the ceiling is greater than that of the air near the floor. This is chiefly due to the heating power of the gas used for lighting, and also (in some measure) to the heat given off from the bodies of the people in the room. The combustion of coal gas gives out a very high temperature; so much so that it is greatly used for cooking purposes. And the air surrounding a gas jet no doubt quickly picks up the heat emitted and rises to the ceiling level. Again, the heat radiated from the surface of the human body has no initial downward direction, and therefore it slowly rises, borne by the air to which it has been imparted by contact. But there is no evidence to show that the high temperature of the air near the ceiling is due to rising of the expired breath of the occupants; nor does it seem an obvious disadvantage to the condition of the atmosphere in a room that there is heated air at the ceiling level. If the fresh air is introduced just above head level, it will be well below the ceiling, and probably, in most cases, below the level of the gas jets for illumination; and if the outlet is near the floor level, it would seem that the change is taking place just at that part of the room where it is most desired.

On the above reasoning it is submitted as fairly shown that the best position for the inlets is just above head level; and for the outlets, immediately below the inlets, near the floor level, although it is probable that no universal rule can be laid down for all classes of buildings.

In the ventilation of large halls, workshops, theatres, churches, and any building where large numbers of people collect, there

[1] It would be beyond the scope of these Notes to consider to what extent the calculations above outlined would be affected by the laws of the diffusion of gases.

are different points which must be considered. Where there is a gallery near the roof provision must be made for carrying away the heated air which accumulates there.

In workshops it is sometimes necessary to carry away objectionable foreign matter in the air, at the point where it is generated. Provision should also be made for extracting above large clusters of gas jets, which are capable of so much air vitiation. Again, in restaurants and large public dining-rooms it is always necessary to provide some means of carrying away smoke, which is generated in such large quantities from burning tobacco. In fact every building must be regarded in relation to the uses to which it is to be put, and every case will demand the most careful consideration.

The rules for proportioning the sizes of air ducts and flues are very complicated, and space does not admit of a full discussion of them here. The sizes vary, moreover, with the different systems of ventilation. There is one point that may be mentioned: when the amount of air required for any given room has been ascertained, the size of the air inlet should be such that the velocity of the entering air does not exceed 3 feet per second. Thus if 10,800 cubic feet are required per hour, the amount of air entering per second will be 3 cubic feet. In this case the sum of the areas of the inlets would require to be 1 square foot, so if two were provided, each should have an area of half a square foot; and if three, each should equal one-third of a square foot in area. The ducts which lead to the inlets may be of smaller sectional area, and the velocity of flow in the ducts will therefore be greater than at the inlet. The sum of the areas of the branch ducts should equal the area of the main duct. As a general rule the same sizes would be suitable for the outlet flues.

The amount of radiating surface required to maintain a given temperature inside a room is the first difficulty which presents itself in designing a heating apparatus.

The radiating surface must be sufficient to give out as many heat units per hour as are lost from the room.

Heat is lost by transmission through the walls, windows, floor, and ceiling. It is also carried away by the air used for ventilation.

On the other hand, heat is given out by the lights and the people who occupy the room. It is not usual to take any account of this in an apparatus for an ordinary dwelling. But in the case of any large assembly-hall, church, or theatre, the heat

evolved is very considerable, and should certainly be taken into account. Taking the heat evolved by the lights first, the amount depends upon the number and kind of light; in the case of electric light it is very small, and may be ignored, but with gas light it is not so. According to the quality of the illuminating gas the number of heat units given out in the combustion of 1 cubic foot varies from 650 to 700. Ordinary gas burners are numbered according to the number of cubic feet of gas they consume per hour. A No. 5 burner consumes 5 cubic feet per hour; a No. 6 burner 6 cubic feet. As a matter of fact they probably consume a great deal more. But accepting the amounts as correct, a No. 5 burner gives out when alight say $700 \times 5 = 3500$ heat units per hour; and a hall lighted by 50 such burners receives from the combustion of the gas $3500 \times 50 = 175{,}000$ heat units per hour.

The heat given out by human beings varies with the age, and whether they are actively employed or at rest. In the case under consideration—namely, a hall or assembly-room—the occupants will in most cases be adults at rest; and the heat given off per hour by one adult at rest varies between 350 and 400 units. Taking the smaller amount, a congregation of 250 such people will evolve $350 \times 250 = 87{,}500$ heat units per hour. So the total amount of heat evolved by 250 people in a hall illuminated with 50 No. 5 gas burners will be 262,500 units, and this amount must be subtracted from the amount required to make up for the losses due to transmission through walls, windows, floor, and ceiling, and also that carried away by the air supplied for ventilation.

The heat carried away by air supplied for ventilation can be easily ascertained. The amount of fresh air delivered into a room is equal to the amount which is discharged from the room. The radiating surface of the heating apparatus has to raise the incoming air from the temperature of the external atmosphere to that of the room.

Now, taking the hall previously mentioned, in which 250 people are assembled for a limited period, the total amount of air required will be $250 \times 1500 = 375{,}000$ cubic feet per hour. Now assuming the outside temperature to be 30° and the internal temperature 60°, the heat lost per hour will equal the amount required to raise the temperature of 375,000 cubic feet through a range of 30° F. In order to find out what this is we must know

what the specific heat of air is. The specific heat of a body is the amount of heat required to raise 1 lb. of it through 1° F. But with a gas there is a difference which must be noted. When the temperature of any gas is raised, if that gas is in an unconfined space its volume increases, and its pressure remains the same as it was before. All that happens is, as the temperature rises, some of the gas is forced out of the unconfined space. In other words, its volume increases, and its pressure remains constant. But if that gas were in a confined space, it is obvious that on raising its temperature, the volume, owing to its confinement, cannot increase. Therefore the pressure is increased. In other words, the volume remains constant, but the pressure is increased.

Now it happens that the amount of heat required to raise the temperature of the gas 1° when the volume is constant, and the pressure increases, is not the same as the amount necessary to raise its temperature 1° when the volume increases, and the pressure is constant. Therefore we say that a gas has two specific heats: one when the volume is constant, and one when the pressure is constant.

The two specific heats of air are :—

When the pressure is constant	·2379
When the volume is constant	·1686

The specific heat with which we are concerned is that with constant pressure, viz. ·2379 : and this means that it takes ·2379 units of heat to raise the temperature of 1 lb. of air through 1° F.

The next point to find out is the number of pounds our 375,000 cubic feet of air will weigh. According to Regnault, 1 cubic foot of air at a temperature of 60° F. weighs ·0764 lbs. Therefore if we multiply the number of cubic feet of air by this, it will give the total weight of the air in pounds. And if we multiply the number of pounds of air by the specific heat, it will give the number of units of heat required to raise the air through 1° F. But in the above example the air had to be raised through 30° F. Therefore we must multiply the result by 30 and that will give the total number of heat units required to raise 375,000 cubic feet of air through 30° F.

Our example is as follows :—

Cubic feet.	
375,000 × ·0764	=28,650 lbs. of air.

To raise 28,650 lbs. of air 1° F.

Pounds of air.	Specific heat.	
28,650 × ·2379	. . . .	= 6815·835 units.

To raise 28,650 lbs. of air through 30° F.

Units.	
6815·835 × 30	= say 204,475 units.

This amount will be the number of units of heat carried off each hour by the air supplied for ventilation.

The heat lost through the walls of a building can only be found out by very careful and searching inquiry. It varies with the material of which the walls are composed; the thickness; the height; to a certain extent it also depends upon the condition of the surface and upon the position and prevailing winds.

Great care has been devoted to this part of the subject in Germany. There it is the custom to treat each wall separately; also to take account of the heat lost through floors and ceilings. In America only the external walls are taken into account, and a margin is added to cover the other losses.

Professor Carpenter of Cornell University has kindly allowed the following tables to be printed in this article. They are taken from his book, *Heating and Ventilating Buildings*, published by Messrs. Wiley & Sons of New York, and Messrs. Chapman & Hall, Limited, of London.

TABLE I.—Amount of Heat, in British Thermal Units, passing through Walls, per Square Foot of Area, per Degree Difference of Temperature, per Hour.

Thickness.	Single Wall.		Wall with Air-Space.[2]
	Brick or Stone.	Wood.[1]	Brick or Stone.
Inches.			
4	0·43	0·12	0·36
8	0·37	0·065	0·30
12	0·32	0·045	0·25
16	0·28	0·033	0·21
18	0·26	0·031	0·19
20	0·25	0·03	0·18
24	0·24	0·029	0·17
28	0·22	0·027	0·15
32	0·21	0·025	0·13
36	0·20	0·020	0·12
40	0·18	0·018	0·10

[1] This experiment applies to solid wood; it is evidently of little use when applied to wooden buildings, since these buildings generally present so many opportunities for loss of heat through crevices.

[2] The thickness given, in the above table, of walls with air-space, includes the thickness of the two separate parts of the wall, plus the thickness of the air-space.

The following table, which is also from Professor Carpenter's book, is translated from one prepared by the German Government:—

TABLE II.—For each Square Foot of Brick Wall.

Thickness of Wall =	4″	8″	12″	16″	20″	24″	28″	32″	36″	40″
Loss of heat per square foot per hour per degree difference of temperature . .	0·68	0·46	0·32	0·26	0·23	0·20	0·174	0·15	0·129	0·115

The following table gives the loss of heat for sandstone and limestone walls of various thickness:—

TABLE III.—Loss of Heat through Stone Walls.

Total Thickness.	Sandstone.	Limestone.	Total Thickness.	Sandstone.	Limestone.
Inches.			Inches.		
12	0·45	0·49	32	0·26	0·28
16	0·39	0·43	36	0·24	0·26
20	0·35	0·38	40	0·22	0·24
24	0·31	0·35	44	0·21	0·23
28	0·28	0·31	48	0·19	0·21

The losses through windows, etc., can be computed from the following table:—

Amount of Heat, in British Thermal Units, lost per Square Foot, per Hour, per Degree Difference of Temperature.

	B.T.U.		B.T.U.
Single window . .	1·03	Double skylight . .	0·496
Double ,, . .	0·472	Doors	0·410
Single skylight . .	1·09		

Having obtained the total amount of heat lost per hour, it is now necessary to find out how much radiating surface will be required to give out those units.

The number of units given out per square foot of radiating surface depends upon the temperature of the heating fluid and the temperature of the air surrounding the radiating surface. It also depends upon the material of which the radiating surface is made, and to some extent upon its form.

Heat is given off by radiation and convection: the greater amount by convection.

TABLE IV.—HEAT-UNITS EMITTED PER HOUR PER SQUARE FOOT FROM VARIOUS SURFACES, DIRECT RADIATION, STILL AIR.

Difference of Temperature.	Co-efficient or Amount per Degree Difference of Temperature.				Total per Square Foot per Hour.[1]			
	Horizontal Pipe, Diameter.				Horizontal Pipe, Diameter.			
	6 in.	4 in.	2 in.	1 in.	6 in.	4 in.	2 in.	1 in.
	Radiator, Height.				Radiator, Height.			
	40 in. Massed Surface.	40 in. Thin.	24 in. Massed.	12 in. Thin.	40 in. Massed Surface.	40 in. Thin.	24 in. Massed.	12 in. Thin.
Deg. F.								
10	0·55	0·62	0·66	0·85	5·50	6·7	6·6	8·5
20	1·11	1·25	1·32	1·72	20·2	24·9	26·4	34·4
30	1·18	1·34	1·42	1·84	35	39·7	42·7	55·2
40	1·24	1·40	1·48	1·92	49·6	56·2	59·0	77
50	1·29	1·46	1·54	2·01	64·5	73·0	77	100
60	1·33	1·50	1·58	2·06	79·8	90	95	124
70	1·36	1·54	1·63	2·12	95·2	108	113	148
80	1·40	1·58	1·67	2·18	112	127	133	173
90	1·43	1·63	1·72	2·24	128	147	153	199
100	1·47	1·66	1·76	2·28	147	167	175	228
110	1·51	1·71	1·80	2·34	166	188	198	257
120	1·54	1·74	1·84	2·39	184	208	219	287
130	1·57	1·78	1·88	2·44	203	230	242	318
140	1·61	1·81	1·91	2·48	223	252	266	346
150	1·64	1·84	1·94	2·53	244	276	291	378
160	1·66	1·87	1·97	2·57	265	300	316	410
170	1·69	1·91	2·02	2·62	286	324	341	443
180	1·72	1·94	2·05	2·65	307	348	367	475
190	1·75	1·98	2·09	2·71	330	375	393	512
200	1·78	2·01	2·12	2·76	356	403	415	552
225	1·87	2·12	2·24	2·91	420	477	500	650
250	1·97	2·23	2·35	3·06	493	557	587	762
275	2·07	2·34	2·47	3·22	563	637	670	872
300	2·17	2·45	2·58	3·37	654	742	780	1020
325	2·27	2·55	2·70	3·50	740	840	882	1150
350	2·37	2·67	2·82	3·66	835	945	995	1295

[1] Results divided by 1000 give approximate weight of steam condensed per hour.

The above table is also taken from Professor Carpenter's book. It gives the number of heat units emitted from various surfaces, with direct radiation: *i.e.* when the radiating surface is inside the room it is to warm.

The above table does not apply where the radiating surface is indirect. If there is no mechanical means provided to drive the air rapidly past the radiating surface, the surface becomes surrounded by highly heated air, which reduces the number of heat units given out per hour. It is therefore usual to provide from 25 to 50 per cent more radiating surface for indirect heating without mechanical aid.

With mechanical ventilation, indirect heating surface is more efficient. Generally, the more rapidly the air passes over the surface, the greater the number of heat units emitted. But in any case a definite amount of indirect radiating surface cannot give such a good result as the same amount of direct radiating surface, because a large proportion of the radiated heat is dissipated in the masonry surrounding the air duct. It therefore does not assist in the work of warming the room.

Space does not permit of a close inquiry into the laws relating to the emission of heat from radiating surfaces. There are many conditions which influence the amount. The same superficial area of surface in the form of a horizontal pipe will give a much better result than in the form of a pipe coil, where the piping is massed together in close proximity. The massing of the pipes has the effect of keeping some of them continually surrounded with air at high temperature, thus limiting the amount of heat given out. Again, a low, long radiator will give out a greater number of units than a high, short radiator of equal superficial area. The reason in this case is that the air, which has been heated at the bottom of the high radiator, rises in contact with its surface. The top portion is therefore continually surrounded by air of higher temperature than the lower portion, and, as before explained, gives out fewer heat units.

The losses in efficiency described above refer to the heat given out by convection. There are also corresponding losses from radiant heat. Radiant heat is always given out at right angles to the surface. Therefore when two or more pipes are grouped together, a part of the radiant heat of each falls upon the surfaces of the other pipes and is consequently lost.

It must not be assumed that pipe coils and radiators are

undesirable forms of radiating surface. On account of the economy of space, and superiority of appearance, they are generally admitted to be the best forms in spite of the losses due to their use.

Before leaving this part of the subject, the following table, for which thanks are also due to Professor Carpenter and the publishers of his book, will be found very useful.

It is frequently necessary to decide if a heating apparatus will do the work required, when the external temperature is not at the point mentioned in the specification. If an internal temperature of 70° F. has been guaranteed when the external temperature is 0°, a reference to the table will show what temperature will be obtained at various other external temperatures if the apparatus has been correctly designed.

Although this table was calculated for steam, with radiator at 220° F., it is practically correct for hot-water radiation, or steam at any other pressure.

TABLE V.

Temperature Outside Air.	Coefficient Heat per Square Foot per Hour per Degree.	Total Heat per Square Foot per Hour.	Resulting Temperature of Room.	Difference Temperature Radiator and Room.
·10	1·85	288	64·7	155·3
0	1·8	270	70	150
10	1·75	253	75·1	144·9
20	1·7	236	81	139
30	1·65	218	86·5	133·5
40	1·6	203	93·1	126·9
50	1·55	188	98·7	129·3
60	1·5	172	104·7	115·3
70	1·45	158	110·5	109·5
80	1·4	142	117·1	102·9
90	1·35	130·5	123·5	96·5
100	1·3	117	130·3	89·7

To determine by a test of the apparatus, when the weather is at 50°, whether a guarantee to heat to 70° in zero weather is maintained, operate the apparatus as though in regular use, and note the average temperature of the room. If the room has a temperature equal to or in excess of 98·7°, it would have a temperature of 70° in zero weather, all other conditions, such as wind, position of windows, etc., being the same as on the day of the test.

The American Radiator Co. have kindly consented to allow

the following tables to be used. They are very useful for determining the correct sizes for mains and branches for direct and indirect radiators.

TABLE VI.—HOT-WATER HEATING: DIRECT RADIATORS.

Size of Radiator.	Size of Branch Mains.	
0 to 15 square feet	$\frac{3}{4}$-inch Branch	Ground Floor.
15 to 50 ,,	1 ,,	
50 to 100 ,,	$1\frac{1}{4}$,,	
100 square feet and over	$1\frac{1}{2}$,,	
0 to 20 square feet	$\frac{3}{4}$,,	1st and 2nd Floor.
20 to 70 ,,	1 ,,	
70 to 125 ,,	$1\frac{1}{4}$,,	
125 square feet and over	$1\frac{1}{2}$,,	

TABLE VII.—HOT-WATER HEATING: INDIRECT RADIATORS.

Size of Radiator.	Size of Branch Mains.
0 to 30 square feet	1-inch Branch.
30 to 60 ,,	$1\frac{1}{4}$,,
60 to 120 ,,	$1\frac{1}{2}$,,
120 square feet and over	2 ,,

TABLE VIII.—FOR APPROXIMATELY PROPORTIONING FLOW AND RETURN MAINS TO THE SURFACE IN RADIATORS.

Size of Pipe. Nominal diameter in inches.	Mains.		Branches and Risers.			
	Square feet of Surface in Indirect Radiators in Basement.	Square feet of Surface in Direct Radiators on one or more floors. Average.	Square feet of Surface in Radiators on first floor.	Square feet of Surface in Radiators on second floor.	Square feet of Surface in Radiators on third floor.	Square feet of Surface in Radiators on fourth floor.
$\frac{3}{4}$	0	0	0	40	45	50
1	0	0	50	75	80	85
$1\frac{1}{4}$	100	135	110	120	135	150
$1\frac{1}{2}$	135	220	180	195	210	230
2	225	350	290	320	350	370
$2\frac{1}{2}$	320	460	400	490	525	550
3	500	675	620	650	690	730
$3\frac{1}{2}$	650	850	820	870	920	970
4	850	1,100	1050	1120	1185	1250
$4\frac{1}{2}$	1,050	1,350	1325	1400	1485	1560
5	1,350	1,700				
6	2,900	3,600				
7	3,900	4,800				
8	5,000	6,200				
9	6,300	7,700				
10	7,900	9,800				
11	9,500	11,800				
12	11,400	14,000				

TABLE IX.—LIST OF SIZES OF STEAM MAINS.

Radiation.	One-pipe Work.	Two-pipe Work.
Up to 60 square feet	$1\frac{1}{4}$ inches.	1×1 inches.
60 to 120 ,,	$1\frac{1}{2}$,,	$1\frac{1}{4} \times 1$,,
120 to 200 ,,	2 ,,	$1\frac{1}{2} \times 1\frac{1}{4}$,,
200 to 360 ,,	$2\frac{1}{2}$,,	$2 \times 1\frac{1}{2}$,,
360 to 600 ,,	3 ,,	$2\frac{1}{2} \times 2$,,
600 to 850 ,,	$3\frac{1}{2}$,,	$3 \times 2\frac{1}{2}$,,
850 to 1200 ,,	4 ,,	$3\frac{1}{2} \times 3$,,
1200 to 1600 ,,	$4\frac{1}{2}$,,	$4 \times 3\frac{1}{2}$,,
1600 to 2000 ,,	5 ,,	$4\frac{1}{2} \times 4$,,
2000 to 2500 ,,	6 ,,	$5 \times 4\frac{1}{2}$,,
2500 to 4000 ,,	7 ,,	6×5 ,,
4000 to 5000 ,,	8 ,,	7×6 ,,
5000 to 6500 ,,	9 ,,	8×6 ,,
6500 to 8000 ,,	10 ,,	9×6 ,,

Heating boilers are made in a great variety of patterns in both wrought and cast iron.

They may be roughly divided into two classes: brick set and independent.

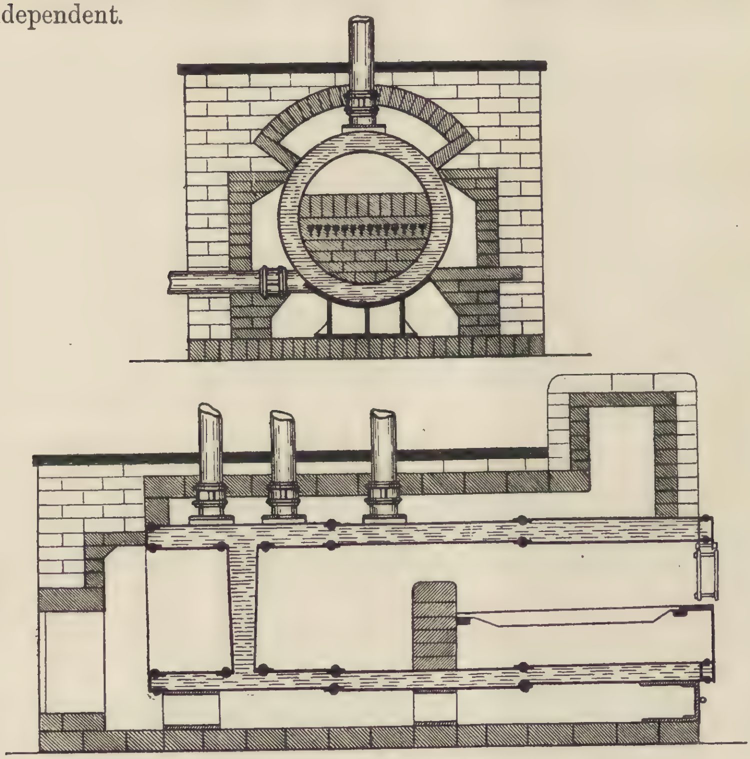


Fig. 310. Brick-set Boiler.

The former are usually of wrought iron; one is shown in Fig. 310.

Perhaps the cast-iron boiler of independent type is the most generally suitable for hot-water and low-pressure steam heating. They are made in sections and have a large heating surface. When covered with a good non-conducting composition they are very economical.

The amount of radiating surface which they are capable of heating is generally correctly stated in the catalogues of the good makers.

Radiators are now used very generally as radiating surface in place of runs of piping.

The illustration (Fig. 311) shows what is called a two-column radiator. In a radiator of this type, each section of which it is composed is divided into two separate columns, which are united at the top and bottom. Fig. 312 shows the elevation and section of a loop. Similarly, in single-column, three-column, and four-column radiators, each section is divided into one, three, and four separate columns, which are united into one at the top and bottom.

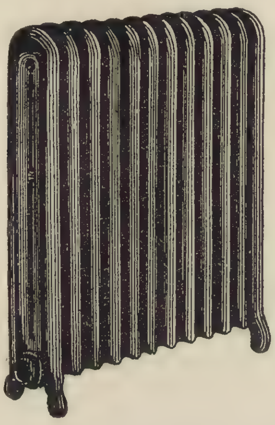


Fig. 311.
Two-column Radiator.

Elevation.

Section.
Fig. 312.

The sections are fixed vertically, and are joined together either with screwed nipples, or turned taper nipples. In the latter case the sections are secured with a horizontal bolt.

The particular advantage of all radiators is the small cubic space occupied by a large amount of radiating surface. In passing through them, the stream of heated water or steam is divided up into streams of small sectional area, from which the heat is given off very rapidly. The amount of heating fluid required is consequently much smaller than in an installation composed entirely of pipes, with the result that a smaller amount of the heat given off by the burning fuel is used up in performing the mechanical work of moving the heating fluid, and a larger proportion of that heat is therefore available for the work of warming the building.

Different patterns of radiators vary very much in efficiency. This is due to the clustering of a large number of surfaces in close proximity to each other. The effect of this, as has been previously described, is to reduce the number of heat units given off.

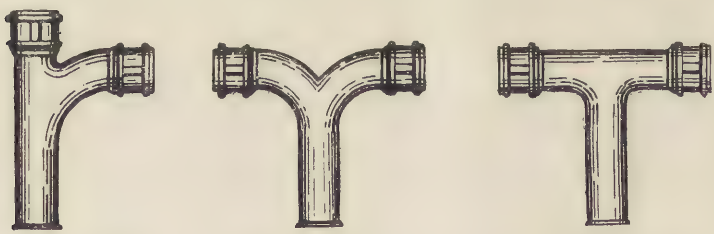
The design of radiators is therefore a matter of considerable importance; they should be of such a form that as large an amount of the radiant heat, which is always emitted at right angles to the surface, escapes freely into the room, without falling upon other parts of the radiator.

Thus if a radiator is built up of two rows of vertical rectangular columns, in which the four sides of the rectangles are equal, only one-fourth of the radiant heat will fall clear of the surrounding surfaces. Such a radiator would therefore be very inefficient. In the section shown in the illustration, Fig. 312, it will be seen that a much larger proportion of the surface is effective, especially if the loops are connected together with a clear space between each.

For the same reason, a single-column radiator is more efficient than a four-column radiator. It is sometimes necessary to use one of the latter form. For where a large amount of surface is required, it may be convenient to make a sacrifice of the efficiency, in order to keep the dimensions of the radiator within reasonable limits.

But it is a good general rule that it is economical to use radiating surface of as simple a form as possible.

There is another type of radiator known as the Flue pattern. This is intended for use when the radiators are a part of the



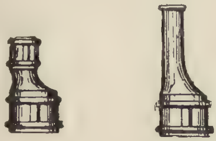
Good Fitting. Good Fitting. Bad Fitting.

Fig. 313.

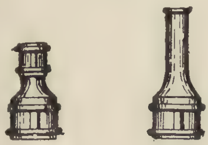
ventilating scheme. In this type a large amount of the radiating surface is boxed in; but this closed-in surface is rendered effective by the rapid passage of air through the flues of the

radiator, carrying into the building by convection heat that would be lost in the form of radiant heat.

This type, when used for the purpose which it is intended to

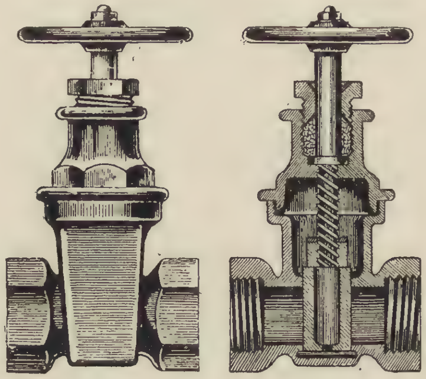


Good Form in Horizontal Pipes.



Bad Form in Horizontal Pipes.

Fig. 314. Diminishing Pieces.



Elevation. Section.

Fig. 315. Full-way Valve.

fulfil, is very efficient, and may be regarded in this respect as equally if not more effective than single-column radiators.

Pipes and fittings are made in both cast and wrought iron. Care should be taken to get only those of the best quality. Inferior pipes and fittings are a source of continual annoyance.

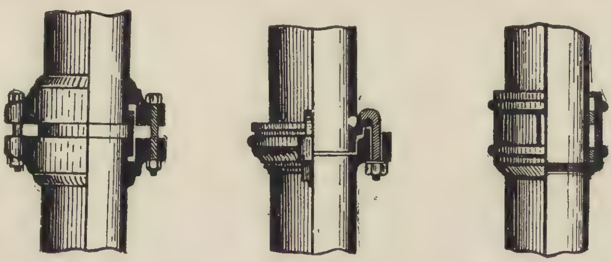


Fig. 316. Cast-iron Pipe-Joints.

Fittings should be selected which offer the least resistance to the flow of the water through them (Fig. 313); where the size of a pipe is diminished, select such fittings that do not form a space in which air can lodge (Fig. 314).

All valves should be full way (Fig. 315).

Some cast-iron pipe-joints are shown in Fig. 316.

CHAPTER XII.

ELECTRIC AND GAS LIGHTING.

THE PRINCIPLES OF DOMESTIC ILLUMINATION.

IN the design of any scheme of artificial lighting, there must always be an adequate amount of light, appropriate in quality, and applied so that it may not react prejudicially upon the eye.

Unit of Light.—The legal standard of light is the amount given by a spermaceti candle, weighing one-sixth of a pound, and burning 120 grains of wax per hour.

Unit of Illumination.—By considering the direct illumination given by a standard candle in connection with the distance of the candle from the object illuminated, a standard of illumination is obtained. Thus the *candle-foot* forms a definite unit, and for any light the illumination at the distance of one foot is expressed in candle-feet numerically equal to the *candle-power* of the light. At distances greater than one foot the intensity of light from a given source varies inversely as the square of the distance from the source. This law is only exact in the rare case of radiation from a minute point into space in which there is neither refraction nor reflection, and in practice it is only useful for general guidance.

A room with dead black walls, lighted by a single candle, affords an example in which the illumination could be determined with approximate accuracy, by the law of inverse squares. But a room with white walls, lighted by a well-shaded light of appreciable area, furnishes an instance in which the law, without qualification, would give very incorrect results.

Intrinsic Brilliancy.—The strength of light per unit area of light-giving surface is termed *intrinsic brilliancy*, and the unit measurement is one candle-power per square inch. Although the intrinsic brilliancy of any light may be mathematically

determined by dividing its candle-power by its area of luminous surface, the correctness of the result so obtained is affected by variation of the brilliancy in the different parts of the light-giving surface. Table X. gives approximately the average intrinsic brilliancies of various sources of light, and will be useful for purposes of comparison. It should be noted that, within fairly wide limits, the efficiency of artificial lighting is by no means proportionate to intrinsic brilliancy.

TABLE X.—Approximate Intrinsic Brilliancy of Various Lights.

Source.	c.-p. per sq. in.
Sun in zenith	600,000
Sun on horizon	2,000
Open arc light (unshaded)	10,000 – 100,000
Nernst "glower" (unshaded)	1,000
Incandescent electric lamp	200 – 300
Enclosed arc lamp (opal inner globe)	75 – 100
Acetylene flame	75 – 100
Incandescent gas lamp	20 – 25
Gas flame	3 – 8
Incandescent electric lamp (frosted)	2 – 5
Opal shaded lamps (various)	0·5 – 2

Undesirable Conditions in Lighting.—As intensely brilliant lights are distinctly injurious to the eyesight, the high brilliancy of the incandescent electric light renders efficient shading particularly desirable. A flickering causes serious strain to the eye, and a similar effect follows the use of alternating current in incandescent lamps if the frequency falls below 30 cycles per second.

Strong contrasts of brilliant illumination and deep shadow are objectionable, and the endeavour should be made to reproduce, as far as possible, the general diffusion of light evidenced in nature.

Amount of Illumination Required.—The minimum strength of illumination required for different purposes may be thus stated:—

Reading and writing	1 candle-foot
Drawing and work on coloured materials	5 candle-feet
Engraving and fine mechanical work	10 candle-feet

Diffusion.—The amount of light diffusely reflected from the walls of any room forms a very considerable proportion of the whole, and coloured walls modify the colour of the illumination as certainly, although not so strongly, as a coloured shade around the source of light. Hence, when settling the colour tone of any room to be illuminated, the designer must bear in mind

that if the walls are to be highly tinted, the preponderating tone of the light will be materially affected.

As a general rule, material assistance is afforded to the lighting of a room by reflection, but the amount of such assistance depends upon the *coefficient of diffuse reflection* (k) of the wall surfaces. Table XI. gives values of the coefficient for various papers and materials.

TABLE XI.—VALUES OF THE COEFFICIENT OF DIFFUSE REFLECTION.

(Direct light of illuminant = 1·00.)

Material.	Value of Coefficient (k).
White paper	0·80
White deal (clean)	0·45
Yellow paper	0·40
Yellow painted wall (clean)	0·40
Light pink paper	0·36
White deal (dirty)	0·20
Yellow painted wall (dirty)	0·20
Emerald green paper	0·18
Dark brown paper	0·13
Vermilion paper	0·12
Blue-green paper	0·12
Cobalt blue paper	0·12
Chocolate paper	0·04
Black cloth	0·012
Black velvet	0·004

Smooth wall-papers and paints reflect a considerable proportion of white light, irrespective of their colour.

In every room there is considerable secondary reflection, having approximately the same coefficient as the first reflection. Hence for two reflections the intensity of the resulting beam is that of the original beam multiplied by the square of the coefficient of diffusion. For each succeeding reflection the next higher power of the coefficient is used.

Shades and Reflectors.—Considered separately, shades are intended to modify the excessive brilliancy of light reaching the eye, and reflectors to modify its distribution, but the two functions are frequently exercised by one fitting.

The essential characteristic of a shade is ability to soften and diffuse the light covered. Cut-glass shades, and others with bands or spirals causing a streaky effect, ought to be avoided. Efficiency is the first essential, and must not be interfered with by decorative attempts.

The average proportion of light absorbed by different shades and globes varies from 10 per cent for clear glass to as much as 60 per cent for opalescent glasses according to their density.

As many forms of light used are of excessive intrinsic brilliancy, too much importance should not be attached to the absorption effected by shades and globes.

The common type of reflecting shade, in the form of a tin cone enamelled white inside, is by no means satisfactory. As shown by the curve of light distribution in Fig. 317, it throws a strong beam of light downwards, but concentrates it too much at one point for general utility.

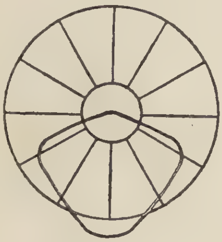


Fig. 317.

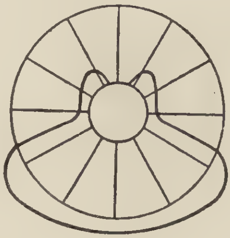


Fig. 318.

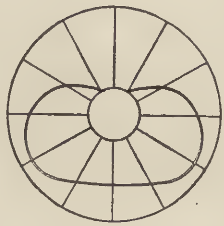


Fig. 319.

A much better shade is one in the form of a fluted porcelain cone, and, as will be seen from Fig. 318, the downward reflection of light is better distributed, and in addition some light is usefully distributed in other directions. Fig. 319 shows the distribution caused by a *holophane* globe with electric light. Numerous forms of shades and reflectors are available both for electric and for gas lighting, and in their selection the greatest attention should be paid to the suitability of the effect likely to be produced for any particular purpose.

The Illumination of Rooms.—In the rooms of a dwelling-house the eyes are not usually fixed in one particular direction, as happens in offices or workrooms, and it is consequently very desirable to avoid intense and unshaded lights of any kind.

A good rule for guidance in the disposition of lights is to provide a moderate groundwork of general illumination, and to concentrate additional light only at such points where it may be required. In the application of this rule it is necessary to consider (1) the amount of illumination, and (2) the kind of illuminant. In connection with (1), the diffuse reflection of direct light must be taken into account.

Let L represent a given quantity of light afforded by the source in any room, and k the coefficient of reflection. Then the total illumination at any point will be, for one reflection, $L(1+k)$; for two reflections, $L(1+k+k^2)$; and so on, using the next

higher power of k for every additional reflection. As k must be less than unity, the series is governed by the limiting value $L\left(\frac{1}{1-k}\right)$. This expression may be applied to calculate the relative effect of the walls upon the light directly radiated into a room.

Referring to Table II., we find that the value of k for an average wall surface may be taken at 0·35. Taking L at unity, we get $L\left(\frac{1}{1-k}\right) = 1\left(\frac{1}{1-0{\cdot}35}\right) = 1{\cdot}53.$

This means that the effective value of the light is increased about 50 per cent by the aid of diffuse reflection, and this result represents fairly what is likely to happen in an ordinary room of moderate size.

Calculation of Light Required.—The intended use of the room to be lighted must always be considered in the arrangement of the lights if economy is to be attained.

Let Fig. 320 be the plan of a room, measuring 20 feet square by 10 feet high, to be lighted so that it may be easy to read and write in any part of it. For this purpose a minimum illumination of one candle-foot will be required on the surface of a plane, say 3 feet above the floor level.


Fig. 320.

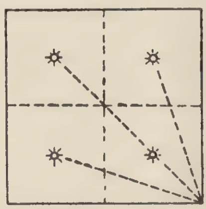


Fig. 321.

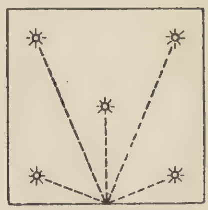


Fig. 322.

Assume the source of light, which we will denote by the symbol S, to be in the middle of the room, and at a height of 4 feet above the plane to be illuminated. Then the distance from the centre to any corner of the plane will be $10 \times 1{\cdot}41421 = 14{\cdot}1421$ feet, and the distance from S to any corner of the plane will be $\sqrt{14{\cdot}1421^2 + 4^2} = \sqrt{216} = 14{\cdot}7$ feet. By the law of inverse squares, each candle-power at S will give only $\frac{1}{216}$ candle-foot at any corner of the room, or $\frac{1}{144}$ candle-foot allow-

ing 50 per cent for augmentation by diffuse reflection. Consequently the light at S must be of 144 candle-power to give adequate light in the corners, but, as excessive light will be given near the middle of the room, this represents an extremely wasteful method of lighting.

Next let us assume the source of light to be subdivided, as shown in Fig. 321, where one light is in the centre of each quarter of the room. Any corner of the plane to be illuminated will now receive varying contributions of light from the four points which we will denote by the symbols s_1, s_2, s_3, s_4. Considering the right-hand bottom corner in the diagram, its distances from the sources of light will be approximately $s_1 = 8$ feet, s_2 and $s_3 = 16$ feet, $s_4 = 22$ feet. Expressing in decimal fractions the proportions of light received, in accordance with the law of inverse squares, at the corner for each candle-power at the different sources, we have:

$$(0{\cdot}0156 + 0{\cdot}0039 + 0{\cdot}0039 + 0{\cdot}0020) = 0{\cdot}0254 \text{ candle-foot,}$$

or, adding 50 per cent for diffusion, 0·0381 candle-foot. Hence the value of the illuminant at each point must be $(1 \div 0{\cdot}0381) =$ 26·24 candle-power. The total illuminating power required is $26{\cdot}24 \times 4 = 104{\cdot}96$ candle-power, which represents a saving of more than 25 per cent as compared with the previous example.

A still more economical arrangement is shown in Fig. 322, where one light is in the centre of the room, and the others on an inscribed circle. On calculation it will be found that the value of the illuminant at each point need only be 17·09 candle-power, or a total of 85·45 candle-power for the five points, representing a further economy of nearly 20 per cent.

In rooms where work is confined to one or more points the arrangement shown in Fig 322 may be modified with advantage by increasing the power of the lamps at such points, and reducing it at the others.

For ordinary living-rooms an arrangement such as that in Fig. 322 might be unsuitable, as the disposition of the lights is generally influenced by structural and artistic considerations. In rooms of this class uniform lighting is not necessary, and it will be sufficient to provide a general illumination of, say, 0·5 candle-foot, with an additional illumination of 1 candle-foot in parts where a bright light is required for reading, writing, or other occupations. In dining-rooms a good central lamp with two or

more small lamps on brackets will amply suffice, and in bedrooms the endeavour should be to place the lights where they will be useful, rather than to produce a general lighting effect.

The laws governing domestic illumination may be thus expressed:

$$L = \frac{C}{d^2}, \qquad C = Ld^2, \qquad d = \sqrt{\frac{C}{L}};$$

where L = illumination in candle-feet at any point;
C = candle-power of the illuminant;
d = distance in feet from the illuminant.

When light is received at any point from more than one source, the first of these equations becomes

$$L = C\left(\frac{1}{d^2} + \frac{1}{d_1^{\,2}} + \ . \ . \ . \ \frac{1}{d^2_n}\right)\left(\frac{1}{1-k}\right);$$

The additional expression $\left(\frac{1}{1-k}\right)$ gives the effect of diffuse reflection for different kinds of wall-surface, k being the coefficient for which values are given in Table XI.

TABLE XII.—Light required for Rooms and Corridors.

In candle-power for an area of 10 square feet.

Description.	Candle-Power.
Dwelling-Houses.	
Entrance Halls	2 – 3
Dining-Rooms	3 – 3½
Morning-Rooms	2½ – 3
Reception-Rooms	2½ – 4
Music-Rooms	3 – 5
Conservatories	2 – 3
Libraries	3 – 3½
Smoking-Rooms	2½ – 3
Boudoirs	3 – 3½
Bedrooms (principal)	1½ – 2
,, (servants')	1 – 1½
Bathrooms, etc.	1½ – 2
Hotels.	
Drawing-Rooms	5 – 7
Bedrooms	2 – 4
Corridors and Subsidiary Rooms	1 – 1½
Offices.	
General Offices	5 – 6
Private Offices	2 – 3½
Corridors and Subsidiary Rooms	2 – 2½

Table XII. is generally applicable to ordinary lighting, but the amount of illumination must necessarily be varied according to the circumstances of particular cases. In exceptionally high rooms the light must be proportionately increased, to compensate for the higher position of the lamps and for the smaller amount of diffused reflection.

The Illumination of Large Rooms and Halls.—In several respects the lighting of large interiors involves considerations that do not occur in connection with the illumination of small rooms. Comparatively little assistance is afforded by diffuse reflection, and the amount of light required is governed more by cubical measurement than by floor area. It generally happens that the height of the illuminant above the plane of illumination is increased proportionally to the height of the room. Consequently the candle-power must be increased to compensate for the greater distance to be traversed by the rays, and this requirement permits the employment of lamps and burners that are inadmissible or inadvisable for rooms of moderate dimensions.

In large apartments ranging from 1,000 to 5,000 square feet area, adequate illumination is secured by providing about 3 candle-power for every 10 square feet of floor-space. This proportion applies when the wall-surfaces are of light colour, and when the lights are suspended in suitable positions not more than 15 feet above the floor.

If the lights are arranged as a frieze, or are fixed on the ceiling, from 30 per cent to 50 per cent more illuminating power will be necessary. Frieze and ceiling lights form a useful groundwork of illumination for halls and ballrooms if supplemented by lights on pendants or wall-brackets.

Workrooms and Workshops.—For workrooms and workshops a sufficient number of lights should be provided for general illumination, and specially arranged lights with suitable shades and reflectors over machines, benches, and tables where brilliant illumination is required. In such places the general illumination should be on the basis of $2\frac{1}{2}$-3 candle-power for every 10 square feet of area, and local illumination should be from 1 to 3 candle-feet, according to the character of the work.

Shops and Showrooms.—For lighting shops where textile fabrics are sold a white light is generally desirable, and the candle-power should be varied with the general tone of the

materials handled in different branches of the trade. Electric arc lamps and Nernst lamps are the most suitable for preserving colour distinction, but it is frequently necessary to employ correctly tinted shades to neutralise the bluish colour of the enclosed arc light. Incandescent electric lamps are practically useless for colour distinction, but incandescent gas lamps give fairly satisfactory results if used in conjunction with pink shades to correct the greenish hue of the light.

THE CHOICE OF ILLUMINANTS.

In selecting the medium of illumination various points must be taken into consideration. A matter of great importance from the hygienic point of view is the effect produced upon the atmosphere of a room by the combustion therein of illuminating material. The data contained in Table XIII. require little comment, the most remarkable feature being the vitiation of air, expressed in terms of adult persons.

TABLE XIII.—Effects produced by the Combustion of various Illuminants. (Per Hour.)

Material.	Quantity.	C.P.	Oxygen Consumed. (Cub. ft.)	Moisture. (Cub. ft.)	Heat. (Calories.)	Vitiation. (Adults.)*
Paraffin Oil . .	992 gr.	16	6·2	3·5	1030	7·5
Kerosene Oil .	909 gr.	16	5·9	3·3	1030	7·0
Gas, Batswing .	5·5 c. ft.	16	6·5	7·3	1192	5·0
,, Argand .	4·8 c. ft.	16	5·8	6·4	1241	4·3
,, Welsbach .	3·5 c. ft.	50	4·1	4·7	763	3·0

* The vitiation caused by one adult person = 1.

The incandescent electric lamp is the best of all illuminants for interior lighting, as it gives a steady light, causes little heat, and does not vitiate the atmosphere. Such lamps should always be in ground glass bulbs, or be sufficiently shaded in order to modify their excessive intrinsic brilliancy.

For the illumination of large interiors and outdoor spaces the enclosed arc lamp and the Nernst lamp will be found more advantageous.

When used with the incandescent burner, gas is the most economical illuminant for domestic use, if burners of appropriate power be employed. Owing to the high intrinsic brilliancy of the light, incandescent gas burners should always be suitably shaded.

In point of quality the incandescent electric lamp and regenerative gas lamps deserve the first place, while incandescent gas and enclosed arc lamps, owing to their colour, and open arc lamps, by reason of their unsteadiness, take a decidedly lower position.

In respect of economy, open arc lamps come first; incandescent gas lamps second; and enclosed arc lamps, incandescent electric lamps, and ordinary gas lights last.

It is probable that the Nernst lamp, and possibly the mercury-vapour lamp,[1] will ultimately take rank with the open arc in point of economy.

Electric Incandescent Lamps.—Cheap foreign-made lamps cost a few pence less than good English lamps, but as they last only two-fifths of the time and consume far more current for a given duty, they are very costly in the end. Well-made and reliable lamps can be obtained at reasonable prices and should always be employed.

TABLE XIV.—Current required by Electric Incandescent Lamps.

Lamps.		Ampères at various voltages.					
Efficiency per c.-p.	c.-p.	100 v.	105 v.	110 v.	200 v.	210 v.	220 v.
		Amps.	Amps.	Amps.	Amps.	Amps.	Amps.
4 watts.	8	0·32	0·30	0·29	0·16	0·15	0·14
	16	0·64	0·61	0·58	0·32	0·30	0·29
	20	0·80	0·76	0·73	0·40	0·38	0·36
	25	1·00	0·95	0·91	0·50	0·48	0·45
	32	1·28	1·22	1·16	0·64	0·61	0·58
3·5 watts.	8	0·28	0·27	0·25	0·14	...	...
	16	0·56	0·53	0·51	0·28	0·27	0·25
	20	0·70	0·67	0·64	0·35	0·33	0·32
	25	0·87	0·83	0·80	0·44	0·42	0·40
	32	1·12	1·07	1·02	0·56	0·53	0·51
	50	1·75	1·63	1·59	0·87	0·83	0·80
3 watts.	16	0·48	0·46	0·44	0·24	0·23	0·22
	25	0·75	0·71	0·68	0·37	0·36	0·34
	32	0·96	0·91	0·87	0·48	0·46	0·44
	50	1·50	1·43	1·36	0·75	0·71	0·68
	100	3·00	2·86	2·73	1·50	1·43	1·36
	150	4·50	4·29	4·09	2·25	2·14	2·04
	200	6·00	5·71	5·45	3·00	2·86	2·73
2·5 watts.	16	0·40	0·38	0·36	0·20	0·19	0·18
	25	0·62	0·59	0·57	0·31	0·30	0·28
	32	0·80	0·76	0·73	0·40	0·38	0·36
	50	1·25	1·19	1·14	0·62	0·59	0·57
	100	2·50	2·38	2·27	1·25	1·19	1·14
	150	3·75	3·57	3·41	1·87	1·79	1·70
	200	5·00	4·76	4·54	2·50	2·38	2·27

[1] At the time of writing, the mercury-vapour lamp is only just being introduced in a commercial form.

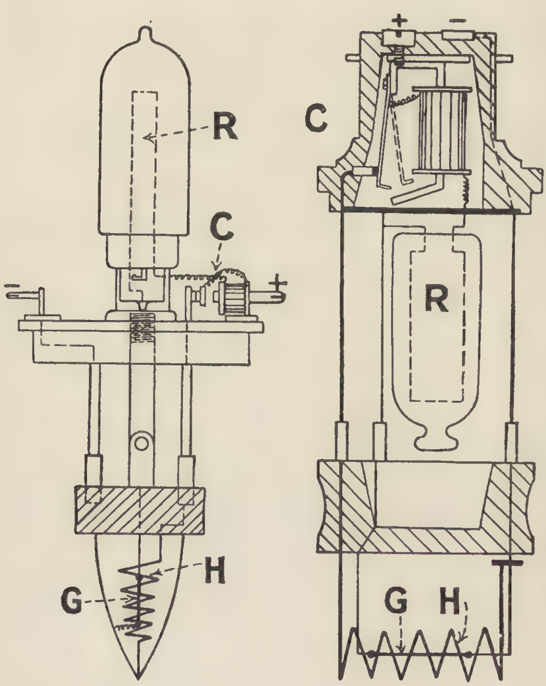
The life of an incandescent lamp is generally taken to be 1,000 hours, but it is not economical to operate it too long, as after 600 hours the light given out is reduced to about two-thirds of the original amount. Hence the lighting of a room may become very unsatisfactory if the lamps are used beyond a certain stage.

Table XIV. gives the current required by incandescent lamps of different sizes and efficiencies at various voltages.

It is always necessary to use lamps suitable for the voltage at which current is supplied. The following efficiencies give the best average results in practice:—

Candle-Power.	Efficiency.
5 – 16	4·0 – 3·5 watts per c.-p.
16 – 32	3·5 – 3·0 ,,
50 and above.	3·0 – 2·0 ,,

The Nernst Lamp.—In this special form of incandescent lamp the filament consists of rare earths akin to those used in the incandescent gas mantle. The filament or "glower" is much more refractory than carbon, and can be carried to far greater incandescence without failure, but being a non-conductor when cold, it must be heated before current will pass. Fig. 323 shows the general arrangement of types A and B of the Nernst self-lighting lamp, the chief parts of which are the glower G, the heater H, the automatic cut-out C, and the resistance R. After entering the + terminal, current passes through the heating coil H, and out



Type A. Type B.

Fig. 323.

through the − terminal. When the heater has been in circuit a few seconds, the glower becomes hot enough to act as a conductor. Current then passes through the automatic cut-out, the resistance R, the glower G, and thence out of the lamp. The glower does not work satisfactorily in an exhausted bulb, and is simply protected from draught and dust by a glass shade or globe.

As produced at the present time, these lamps have an initial efficiency of less than 2 watts per candle, and the average useful life of a burner is about 400 hours.

The Nernst lamp is made in sizes ranging from 15 to 150 candle-power, and in various patterns suitable for domestic and outdoor lighting. It is important that continuous-current lamps should be connected with due regard to polarity. The positive pole on each lamp is marked with a + sign.

Linolite.—This is the name given to a new form of the incandescent lamp, and consists of straight carbon filaments contained in glass tubes, which are connected together and fitted into metal reflectors as shown in Fig. 324. The sides of the reflectors are bent over to form conduits for the wires, and the complete arrangement can be attached to walls, or hung from picture rails, so as to throw the light directly into the space to be illuminated, or against the ceiling for reflection.

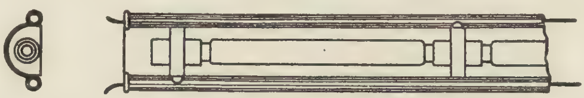


Fig. 324.

Electric Arc Lamps.—Arc lamps are made in two types, "open" and "enclosed." In the former, air has free access to the carbons, and in the latter the carbons are enclosed in a closely fitting globe which keeps the space round the arc nearly free from oxygen. Both types can be used with either continuous or alternating current.

The two systems of running arc lamps are (1) on a constant current, in *series*, and (2) on a constant potential, either in *series* or in *parallel*. In the first system, each lamp must have an automatic cut-out, so that the failure of one lamp may not extinguish the remainder. In the second system, when continuous current is used, each lamp must have an automatic *resistance* acting when one lamp fails, so that the others may burn steadily.

When alternating current is used, a *choking coil* takes the place of the *resistance.*

Open arcs of from 6 to 20 ampères require across the carbons from 40 to 45 volts continuous current, and from 30 to 35 volts alternating current. Enclosed arcs require double the voltage and half the current necessary for open arcs.

The relative efficiency of different forms of arc lamps is stated approximately in Table XV. on the basis of mean spherical candle-power.

TABLE XV.—COMPARISON OF ARC LAMPS.

In Watts per Mean Spherical Candle-Power.

Type of Lamp.	Current.	Watts per Spherical Candle-Power.	Notes.
Open, not shaded .	Continuous	1·0	Medium power.
,, shaded .	,,	1·3	,,
,, not shaded .	Alternating	1·7	
,, shaded .	,,	2·2	
Enclosed . .	Continuous	1·9	Series lamp.
,, . .	,,	2·4	Outer globe, none.
,, . .	,,	2·9	,, clear.
,, . .	,,	3·3	,, opal.
,, . .	Alternating	2·5	,, none.
,, . .	,,	3·0	,, clear.
,, . .	,,	3·6	,, opal.

In lighting large workshops with the open arc, unnecessarily dazzling light and dark shadows may be avoided by inverting the arc and reflecting the light upon a whitewashed surface for diffusion.

In continuous current arc lighting, the top carbon is connected to the positive conductor for direct illumination, and to the negative conductor for reflected light. With alternating current the light is thrown equally up and down, and for direct illumination a reflector is fitted above the arc to throw the light downward.

The light given by the enclosed arc lamp is much more steady and is better distributed than that afforded by the open type.

Ordinary Gas Burners.—Flat flame burners of the *batswing* and *fishtail* variety are very inefficient unless of fairly large size. With coal gas of 16 candle-power nominal value, a 4 ft. burner will not give more than about 2·5 candle-power per cubic foot, while a 5 ft. burner gives from 2·75 to 3 candle-power per cubic foot.

Argand Burners.—These give better results than ordinary burners owing to the enclosure of the flame by a chimney. The efficiency of a good Argand burner is from 3 to 3·5 candle-power per cubic foot with 16 candle-power gas.

Regenerative Gas Lamps.—Burners such as those used in the Wenham and Siemens regenerative lamps have been largely used for powerful lights. They are based on the principle of heating both the gas and the air. The burner itself somewhat resembles an inverted Argand arranged so as to furnish a circular sheet of flame, convex downwards. Directly above the burner are the gas and air ducts.

The light given by such burners is a brilliant yellow-white, with a good hemispherical distribution downwards. With 16 candle-power gas, their efficiency is from 5 to 7 candle-power per cubic foot, but they are most economical in large sizes ranging from 100 to 200 candle-power.

Incandescent Gas Lamps.—Although their composition has been kept more or less a secret, it is known that the incandescent mantles consist essentially of the refractory oxides occurring as components of certain rare minerals. When highly heated these substances give most brilliant incandescence with a small expenditure of gas. The necessary heat is furnished by a Bunsen burner within the mantle.

As in most gas burners, the efficiency of the mantle burner increases with its size, but the average light given is from 12 to 15 candle-power per cubic foot of gas consumed.

When the burner is new, its efficiency as compared with other gas burners is approximately in the following ratios:—

Regenerative burner 3 : 1; Argand burner 5 : 1; ordinary burners 6 : 1. This efficiency is not maintained, as after burning for about 300 hours the light yielded is little more than two-thirds the original amount.

The chief objections to the incandescent burner are (1) that the light has an unpleasant greenish hue; (2) that the smallest size procurable is of 50 candle-power; and (3) that much of the light is prevented from falling on the surface to be illuminated.

The first drawback may be modified by the use of pink shades, the second cannot be remedied by the purchaser, and the third may be corrected to some extent by suitable reflecting shades.

The Inverted Incandescent Gas Lamp.—This new form of the

incandescent gas lamp possesses features that render it very suitable for domestic lighting.

Fig. 325 is a section showing the essential parts of the new inverted lamp. The socket *a* is screwed for connection to a bracket or other fitting; *b* is an air regulator consisting of a sleeve with holes which can be rotated on an inner tube provided with holes of corresponding size; *c* is a set-screw for fixing the air regulator. Gas and air are mixed in the chamber *d*, and delivered through the pipe *e*, in the china cone *f*, at the end of which the mixture burns with a Bunsen flame. The cone *f* acts both as a radiator and reflector, and is provided with projections forming a bayonet-joint for supporting the mantle *g*; three arms, of which only two, *hh*, are here seen, carrying a gallery *j*, for attachment of the globe *k* by means of set-screws.

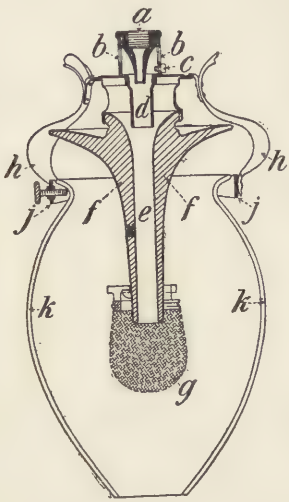


Fig. 325.

Fig. 326 represents a complete lamp, with a 70 candle-power mantle burner, the consumption of which is stated to be 3·2 cubic feet of gas per hour. Fig. 327 represents a complete lamp with a 20 candle-power burner, requiring 1 cubic foot of gas per hour. By-passes can be fitted to either of these lamps. Fig. 328 shows the application of a lamp to an existing gas bracket by means of an "adapter."

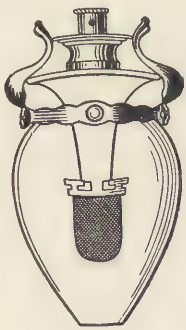


Fig. 326.

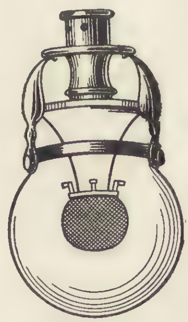


Fig. 327.

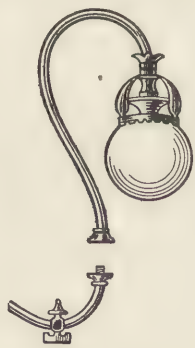


Fig. 328.

From these illustrations, which are not intended to show relative sizes, it will be seen that the general appearance of this lamp very much resembles that of an incandescent electric lamp.

In this type of incandescent gas lamp most of the light is thrown downwards, no shadows are cast on the surfaces to be illuminated, and the light is free from the greenish hue of the ordinary incandescent mantle burner. The smaller sized burners represent another important advantage, as they can be employed for the more efficient distribution of light and for the more artistic arrangement of lamps in large rooms. They are also useful for lighting small apartments where an ordinary mantle burner would be far too powerful, as well as being extravagant in respect of gas consumption. Further, the new inverted lamp does not blacken ceilings to anything like the extent experienced with other gas burners and lamps.

ELECTRIC LIGHT INSTALLATION.

Electrical Definitions and Laws.—Scientific definitions of electrical units of measurement are based on the C.G.S. system, in which the three symbols represent centimetres, grammes, and seconds. In the following notes we deal only with such practical definitions and simple laws as may be required in connection with electric light installations.

The *Ampère* is the unit of current. The current flowing per hour is commonly taken as the unit of quantity, and is measured in *ampère-hours.*

The *Ohm* is the unit of electrical resistance.

The *Volt* is the unit of electromotive force (E.M.F.) or potential difference (P.D.), generally termed electrical "pressure," and is the electromotive force required to send one ampère through a resistance of one ohm.

The *Watt* is the unit of power or rate of doing work, and is the power absorbed in a circuit when a current of one ampère flows between two points having a potential difference of one volt. Hence, 1 watt = 1 ampère × 1 volt.

An *electrical horse-power* = 746 watts.

The amount of power absorbed per hour is taken as a unit of energy and is measured in *watt-hours.*

The *Board of Trade Unit* is the commercial unit of electrical energy, and is equal to 1000 watt-hours.

For convenience in writing and speaking of large and small quantities of units, various prefixes are employed.

Thus—

Megohm = one million ohms.
Kilowatt = one thousand watts.
Microhm = one millionth of an ohm.
Milliampère = one thousandth of an ampère.

A glossary of some frequently used electrical terms will be found in Appendix I., p. 373.

Ohm's Law.—In every electrical circuit the three factors—electromotive force, current, and resistance—are always present. These are connected by the relationship enunciated in Ohm's Law. Let C = current, E = electromotive force, and R = resistance.

Then

$$C = \frac{E}{R}, \quad R = \frac{E}{C}, \quad \text{and } E = C \times R.$$

Nearly all the calculations required in electric wiring are based on these simple equations.

Laws of Resistance.—The resistance of any conductor is directly proportional to its length, inversely proportional to its area, and directly proportional to the specific resistance of the material.

Let R = resistance of a rod of material, l = length of the rod in inches, A = cross-sectional area of the rod in square inches, and p = specific resistance of the material per cubic inch.

Then

$$R = \frac{pl}{A}.$$

If p be expressed in C.G.S. units, l must be in centimetres and A in square centimetres.

As resistance increases with the increase of temperature due to the passage of current through a conductor, the following formula is used for calculating the resistance of a conductor at a given temperature from its known resistance at a lower temperature. Let R = resistance at the lower temperature, R_1 = resistance at the higher temperature, t = difference in temperature, and $\propto$ = temperature coefficient.

Then

$$R_1 = R(1 + \propto t).$$

Data for the resistances and weights of copper conductors will

be found at p. 387 in the Appendix to the Wiring Rules of the Institution of Electrical Engineers.

A Key Diagram explanatory of the wiring and other diagrams contained in this chapter will be found on p. 339.

ELECTRIC CURRENT FOR LIGHTING.

These notes refer to the available sources of supply, and contain brief particulars of the plant necessary for a private generating station.

Public Sources of Supply.—In most cities and large towns current is supplied from central stations, and brought into the premises to be lighted, for connection to the wiring system. As a general rule, meters are provided by supply corporations, and charges are based on the consumption in Board of Trade Units. The price per unit varies considerably in different districts, and rates are usually fixed in accordance with the *maximum demand system*, which provides for a considerable reduction in the price for current used after the first hour in each day.

Current for lighting is supplied in two forms: (1) as *continuous or direct current*, and (2) as *alternating current.*

Continuous current apparently flows in one direction through the conducting system, while alternating current exhibits a complete cycle of changes, both of magnitude and of direction, at regular intervals of time. The time occupied by a complete *cycle* is called the *period*, and the number of cycles per second is termed the *periodicity* or the *frequency* of the current.

As comparatively few supply corporations furnish alternating current for lighting, all subsequent notes will refer, unless otherwise specified, to systems in which continuous current is employed.

Private Sources of Supply.—Cases often occur in which the installation of private generating plant is either desirable or absolutely necessary. Business premises and public buildings in towns, and large dwelling-houses in suburban districts, can generally be supplied with current from private generating plant at lower cost than from a public source, while similar buildings in country districts are frequently situated in places where current cannot be purchased. Further, it should be remembered that water-power is sometimes available for the cheap generation of electricity in country districts. The essential units of a private generating plant are briefly discussed in the subjoined notes.

Motive Power.—Steam-engines specially designed for electric lighting are now available in all sizes, but unless steam-power is also required for other purposes this form of prime mover is not to be recommended. Gas and oil engines are far more economical for small private installations. Recent improvements render either type of motor perfectly suitable for adoption, and the amount of personal attendance required is so small that the engagement of additional help is rarely necessary.

The consumption of gas in a modern engine is 15-25 cubic feet per brake horse-power. Taking the upper limit, the consumption per kilowatt is $(25 \times 1000) \div 746 = 33{\cdot}5$ cubic feet, or, allowing for losses, say 37·5 cubic feet. With gas at 2s. 6d. per 1000 cubic feet, the cost of fuel works out at about 1·12d. per Board of Trade Unit.

The consumption of oil in a well-designed engine at full load is not more than 0·82 lb. per brake horse-power. On this basis the consumption per kilowatt is $(0{\cdot}82 \times 1000) \div 746 = 1{\cdot}09$ lb., or, allowing for losses, say 1·2 lb. Taking the specific gravity of oil at 0·8, and the price at 6d. per gallon, the cost of fuel works out at 0·9d. per Board of Trade Unit.

The above figures are subject to revision according to local circumstances, but, as fuel is the chief item of expenditure in the generation of electricity, they serve to demonstrate the possibility of producing current at very economical rates in a private station.

The Generator or Dynamo.—This machine converts mechanical energy into electrical energy by the rotation of the armature in a magnetic field. Fig. 329 indicates the essential parts of a bi-polar continuous-current dynamo. The field-magnet coil A carries the current necessary for exciting the field magnet B, which produces magnetic lines of force passing the armature C. Current is generated in the windings D of the armature, at one end of which is the commutator E, where carbon or metal brushes FF collect the current.

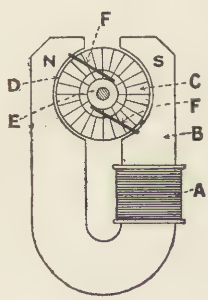


Fig. 329.

Continuous current dynamos are classified according to the method of winding adopted for the field magnets.

(*a*) The *series-wound* dynamo (Fig. 330) is suitable for arc lamps in series, where the current must be constant although the voltage may vary.

(*b*) The *shunt-wound* dynamo (Fig. 331) is used for incandescent lamps, where the voltage must be constant although the current used may vary. These conditions are imperfectly fulfilled by shunt-winding, as any increase of current causes a drop in voltage.

(*c*) The *compound-wound* dynamo (Fig. 332), which combines series and shunt-winding, is most suitable for incandescent lamps, as any increase in the load causes more current to pass round the field magnets, thus maintaining the voltage at its normal value.

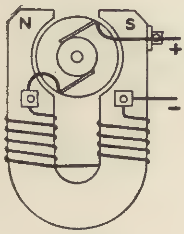


Fig. 330.

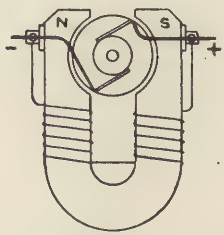


Fig. 331.

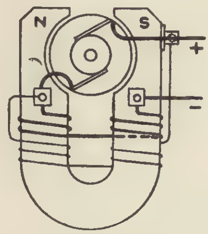


Fig. 332.

Dynamos may be directly coupled to the prime mover, or driven by belting. A comparatively large output can be obtained from a small dynamo running at high speed; and as the speed of a belt-driven machine is not limited by that of the engine, this mode of driving involves less outlay than direct driving. A direct-coupled generating set economises space and is frequently to be preferred.

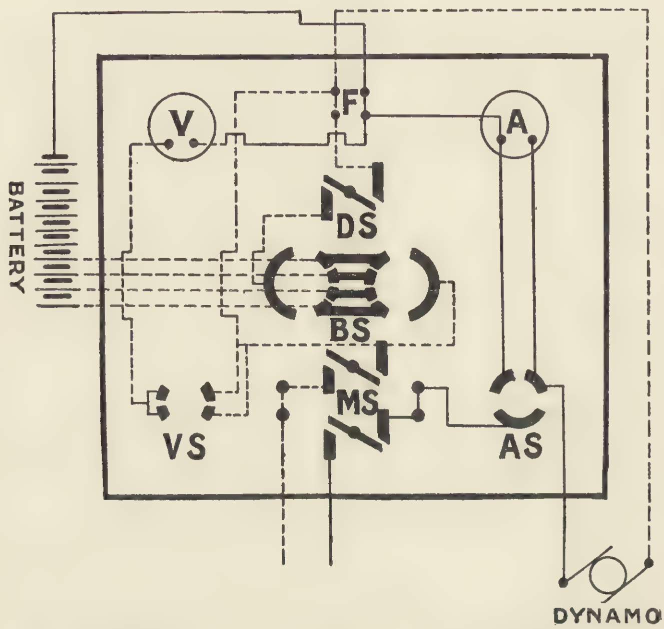
In fixing a belt-driven dynamo, it is always desirable to use a sliding cast-iron bed-plate, with screws permitting adjustment of the belt while the machine is running.

The Storage Battery.—In private installations the use of an accumulator or storage battery is always desirable. The cells can be charged at any convenient time during the day, and a steady supply of current is thereby rendered available at all hours of the day or night.

The cells of a battery are made in various sizes providing specified capacities in ampère-hours. Consequently, it is easy to select cells suitable for the requirements of any given case. The electromotive force of each cell when discharging is about 2 volts for all sizes. Therefore 25 cells = 50 volts, or 50 cells = 100 volts, but in practice it is usual to allow 27 cells for a

50-volt circuit, and 54 cells for a 100-volt circuit, the additional cells being for the purpose of compensating for the inevitable fall of voltage during discharge.

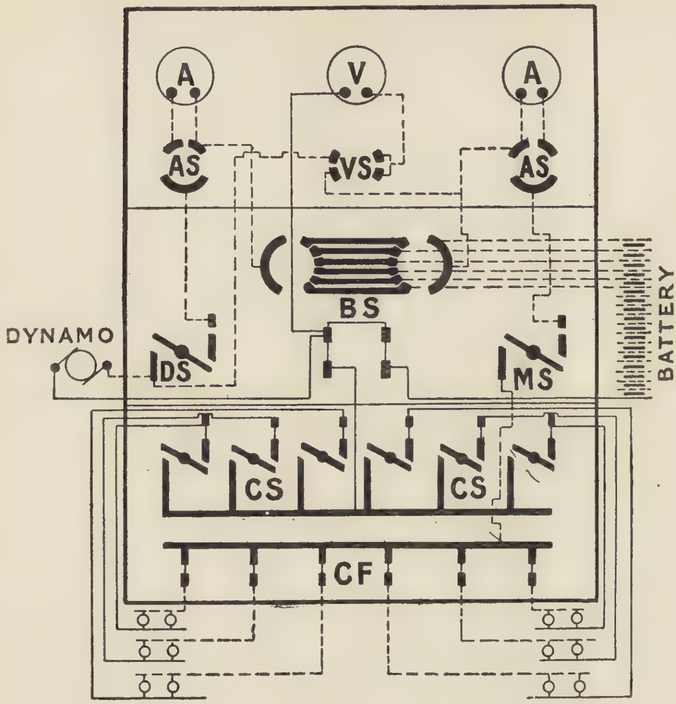
The Switchboard.—In a small installation, where the generator is in an outbuilding, and current is taken direct from the dynamo or battery to the main distribution-board in the house to be lighted, the switchboard is of very simple construction. Fig. 333 is a diagram indicating the instruments and connections for such a board.



V = Voltmeter.	A = Ammeter.
VS = Voltmeter switch.	AS = Ammeter switch.
F = Fuse.	DS = Dynamo switch.
BS = Battery switch.	MS = Main switch.

Fig. 333.

In a larger installation it is often desirable to control the branch circuits from the main switchboard in the generating station. Distribution boards are also provided in different parts of the building, or in the separate buildings to be lighted. Fig. 334 is a diagram showing the instruments and connections for a switchboard of this type, to which the addition of a permanent *earth tester* will afford ready means of detecting faults.



A = Ammeter.
AS = Ammeter switch.
DS = Dynamo switch.
CS = Circuit switch.
V = Voltmeter.
VS = Voltmeter switch.
MS = Main switch.
CF = Circuit fuse.
BS = Battery regulating switch.

Fig. 334.

DISTRIBUTING MAINS.

Under this head we deal with the distribution of electricity from the source of supply to the building or buildings in which it is to be used.

The *two-wire system* is the most suitable for general adoption. In Fig. 335 the lamps are shown in parallel between the positive and negative conductors. The system may be elaborated to any desired extent by the addition of branch conductors, but all the positives must be in direct communication through the apparatus in circuit with the negative feeding-point.

Separate cables can be employed for the positive and negative conductors, or concentric cables may be used.

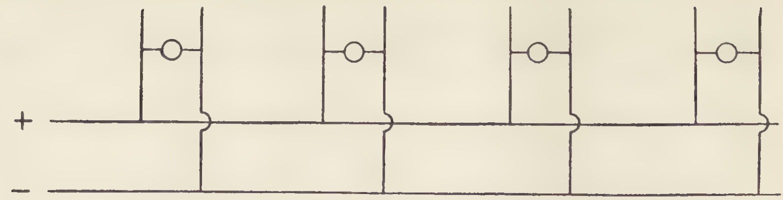


Fig. 335. Two-Wire System.

The *three-wire system* is only to be recommended for large buildings equipped with a private generating station. It may be regarded as the combination of two two-wire systems arranged side by side, and of which the two adjacent wires are replaced by one inner wire, as in Fig. 336. Here the lamps are shown in parallel between the branch conductors, which are taken alternately from the positive and negative mains or *outers;* but all the branch returns are connected to the centre main or *inner.* Thus, if the positive outer be maintained at 200 volts above earth, the negative outer at 200 volts below earth, and the inner at earth potential, the difference between the outers is 400 volts, and between either outer and the inner only 200 volts. The latter is the maximum potential entering the branch circuits. Currents flowing in the inner wire neutralise each other, and there would be no resultant current in the inner if the load were equally balanced.

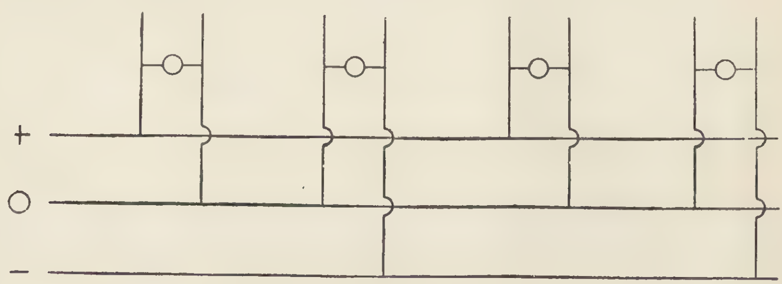


Fig. 336. Three-Wire System.

Owing to the higher potential between the outers and the small amount of current in the inner, the three-wire system requires far less copper than the two-wire system. Table XVI. contains a comparison of the two systems when the area of the inner is taken at one-fourth that of either outer, but in practice the area of the inner should be about two-thirds the area of either outer.

TABLE XVI.—COMPARISON OF TWO-WIRE AND THREE-WIRE SYSTEMS.

Equal voltage on lamps, equal power transmitted, and equal fall of voltage.

Points for Comparison.	Two-Wire.	Three-Wire.
Maximum potential difference	200 volts	400 volts
Current in outers = C	C	$\frac{1}{2}$ C
Resistance of each outer = R	R	4 R
Weight of each outer (no current in inner) .	1	$\frac{1}{4}$
Weight of inner	. .	$\frac{1}{16}$
Total weight of wires	2	$\frac{9}{16}$
Weight of copper	100 per cent.	28 per cent.

The three-wire system is chiefly to be recommended for conveying current from the generating plant to isolated buildings, or to different parts of a large building with a two-wire system for local wiring.

By directly connecting between the outers a high voltage current can be obtained for driving small motors or for arc lighting. Either three separate cables or a triple concentric cable may be used for the conductors.

Conductors.—In cables and wires used for domestic lighting installations, copper is used almost without exception as the conducting material. The metal must be efficiently insulated, so as to prevent the possibility of contact between the positive and negative conductors. The consequence of such contact would be a *short circuit,* suddenly liberating a large amount of electrical energy, probably melting some portion of the conductors, and setting fire to the premises.

If moisture should penetrate the insulation, an *earth* connection will be established, with the result that current will leak from one pole to the other through the moisture or "earth," and if the moisture be a good conductor a *dead earth* connection will be set up. In one event electrolytic action will eat away the positive conductor until the circuit is broken, and in the other the effects may be as serious as those of a short circuit.

In addition to electrical insulation, conductors require mechanical protection against injury.

India-rubber is the best insulating material. It is an excellent non-conductor, is little affected by temperature changes, and permits the cables and wires to be bent safely and readily.

Ordinary cables of the best quality consist of high-conductivity tinned copper wires, insulated with pure and vulcanised rubber,

wound with specially prepared tape, the whole being vulcanised together, and finally covered with an outer sheathing of lead.

Cables of untinned copper wires insulated with diatrine paper and covered with lead are much used in the present day for underground mains. Great care must always be exercised in laying and jointing such conductors, because, if the ends become at all wet, moisture will travel along the insulation causing leakages, the rectification of which may prove to be very troublesome and expensive.

Many different kinds of ordinary and special cables are made, but as full details relative to construction, dimensions, capacity, resistance, and weight are published by the leading makers, it is unnecessary to give detailed particulars in this chapter.

Limiting Temperature of Conductors.—The resistance of any conductor to the flow of an electric current develops heat in a measure directly proportional to the amount of current, and inversely proportional to the area of the conductor. The temperature of a conductor should be kept within reasonable limits for the following reasons:—

1. The resistance of the conductor increases with the increase of temperature.

2. The resistance of the insulation decreases with the increase of temperature.

3. Some insulation materials are softened and some are otherwise injured by heat.

4. The overheating of a conductor occasions risk of fire.

The increase in temperature of a conductor depends upon its electrical conductivity, the nature and extent of the radiating surface, the nature and condition of the surrounding medium, and the specific heat of the metal. In the case of a lighting installation, the conditions vary from point to point, and exact determinations of temperature throughout a distributing system would involve much tedious and unnecessary labour.

On reference to the table at the end of the Wiring Rules of the Institution of Electrical Engineers (Appendix II., p. 376), it will be seen that maximum currents are given, in columns 6, 7, and 10, for two classes of conductors. These permissible currents have been calculated with due regard to the equivalent rise in temperature, and, so far as temperature is concerned, it is quite sufficient to work to this standard without special calculation.

Fall of Potential in Conductors.—The resistance of any con-

ductor to the passage of an electric current causes loss of potential, just as the resistance in a pipe to the flow of liquid or gas causes loss of pressure.

It is always necessary to calculate the loss of potential in conductors, but this is a very simple matter.

$$\text{By Ohm's Law} \quad C = \frac{E}{R}, \quad \text{and } E = C \times R.$$

As $R = L \,.\, r$, or *length of any conductor × resistance in ohms per foot,* we have

$$E = C \,.\, r \,.\, L, \quad \text{and } r = \frac{E}{C \,.\, L}.$$

Let the loss of potential be limited to 2·5 volts in a 100-volt circuit between a dynamo and the building to be lighted. Assume the current to be 500 ampères, and the distance between the two points to be 200 feet, giving 400 feet as the combined length of positive and negative conductors.

Then for the resistance per foot we have

$$r = 2{\cdot}5 \div (500 \times 400) = 2{\cdot}5 \div 200{,}000 = 0{\cdot}0000125 \text{ ohm.}$$

To find a conductor having this resistance we turn to the table facing p. 094, and find by column 7 that a 91/·098″ cable will carry the maximum of 560 ampères, and by column 11 we see that the corresponding loss of potential is 1 volt for a length of 50 yards.

The resistance per foot of conductor is thus found:

$$r = \frac{1}{560 \times (50 \times 3)} = 0{\cdot}0000119 \text{ ohm.}$$

Therefore, by $E = C \,.\, r \,.\, L$, the loss of potential is $0{\cdot}0000119 \times 200{,}000 = 2{\cdot}38$ volts, and the 91/·098″ cable is of ample size.

By a development of this method, the conductors for any system of distribution can be proportioned; but, where many such calculations are required, time will be saved by using a table giving the resistances of cables per foot or for other convenient units.

Conversely, the loss of potential can be calculated from the known current in a circuit of any given length.

Cable Laying.—Underground cables may be laid on the *drawing-in system* or the *solid system.* The latter is always to be preferred.

Drawing-in System.—In the drawing-in system cast-iron pipes

stoneware pipes, or ducts of stoneware, bitumen-concrete, and cement may be used. Whenever possible, one pipe or one compartment should be provided for each cable. Lead-covered cables are almost invariably used.

Cast-iron pipes for use as conduits should have spigot and socket ends, and rounded internal edges, as shown in Fig. 337. Before use it is well to clean the interior of each pipe so as to remove irregularities likely to damage the cables when being drawn in. All bends ought to be provided with hand-holes. The pipes and all fittings should be coated inside and outside with Dr. Angus Smith's composition.

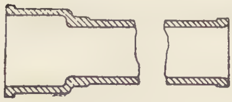


Fig. 337.

Wrought-iron pipes are not to be recommended for underground work, owing to their want of durability.

In making joints, the spigot end of one pipe is pushed into the socket end of the other. A layer of yarn is then wound around the spigot for a width of 1 in. to $1\frac{1}{4}$ in., and rammed down to the bottom of the socket, so that melted lead can be poured into the annular space between the spigot and socket. After the lead has cooled, the clay is removed and the lead is caulked in with a proper tool. When laying the pipes it is well to thread a stout galvanised wire through them, to facilitate the later process of drawing-in the cable. All open ends of the pipe line should be plugged after laying, to keep out water and earth. The ends should be similarly stopped whenever the work of laying is interrupted.

Glazed stoneware drain-pipes with cement joints are also used for the drawing-in system. This form of conduit is open to the objections that any cement from the joints will injure the cable, and that the pipes are apt to be non-concentric at the joints, thus presenting sharp edges likely to damage the insulation during the drawing-in process.

An improvement on the ordinary stoneware pipe-joint is Doulton's ball-and-socket joint, shown in Fig. 338. In this, a composition of sulphur, sand, etc., is moulded upon the pipe ends, so that the spigot end forms part of a sphere, while the socket is part of a cylinder. Before being inserted, the spigot must be well greased; it can then be slid in, and makes a

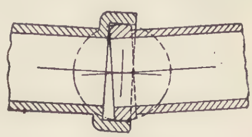


Fig. 338.

perfectly watertight joint. The joint is not broken by moderate sinking of the earth, as the ball and socket allow movement within reasonable limits, while still preserving a watertight fit. There is no danger of non-concentric ends, and the pipes can be laid very quickly.

Other varieties of conduit for the drawing-in system need not be mentioned here, as they are chiefly applicable to public distributing mains.

Doulton's bell-mouth cable protector is illustrated in Fig. 339. These protectors are made to suit the spigot and socket ends of different sizes of iron pipes, and are also made in halves, so that they may be fixed in places where the cables have already been drawn in. The protector is secured by means of cement as shown in the drawing.

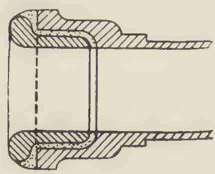


Fig. 339.

In laying pipes of any kind, the size must be ample for the cables to be drawn in. For single cables, the internal pipe diameter should not be less than twice the external diameter of the cable. Wherever practicable, the pipes should be laid in straight lines, and all curves should be as easy as possible.

Cables must never be drawn round sharp bends. Bends must always be fixed in a horizontal plane. The pipe line must never be dipped down and brought up again, thus forming traps for water.

Before commencing to draw in the cable, a swab should be passed through the pipe to clear away earth or other obstructions. Plenty of soft soap should be used as a lubricant, but the soap must be chemically neutral. Great care must be taken to see that the cable is not in any way twisted. This is especially important in the case of a concentric cable. If part of a cable has to be drawn out of a pipe at any point, it should be rolled on a spare drum. It must never be coiled down like a rope.

If a cable has to be cut, the ends should be carefully sealed. Inefficient sealing is sure to cause trouble, especially with paper insulation.

Solid System.—In the solid or built-in system, the cables are laid in wooden, stoneware, iron, or other troughs, which are then filled with melted bitumen and closed by suitable covers. The advantage of this system is that the cables are open to inspection during and after laying; hence they can be tested before the

troughing is filled with bitumen, and any faults can be made good with a minimum amount of trouble and cost.

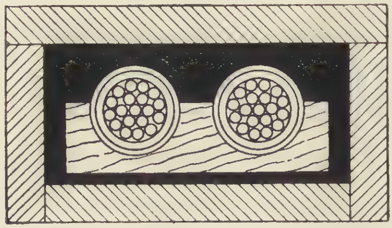


Fig. 340.

Fig. 340 represents a wooden trough for two cables supported on wooden bridges and filled in with bitumen. The troughing should be made in 12 ft. lengths, of pitchpine boards $1\frac{1}{8}$ or $1\frac{1}{4}$ in. thick; the bridges should be $1\frac{1}{4}$ in. thick, and boiled in bitumen before use. Jointing is performed by butting two ends together and enclosing them in a covering trough about 18 ins. long. As a precaution against decay, the troughs should be boiled in Stockholm tar free from creosote.

Timber troughing is found satisfactory, and additional protection against digging or excavating tools can be provided by a thin board laid above the cover, and separated from it by a layer of earth.

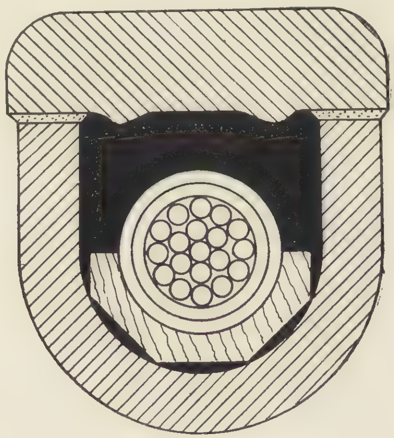


Fig. 341.

Fig. 341 represents a stoneware trough for a single cable, and

Fig. 342 similar troughing for a three-wire system. In each

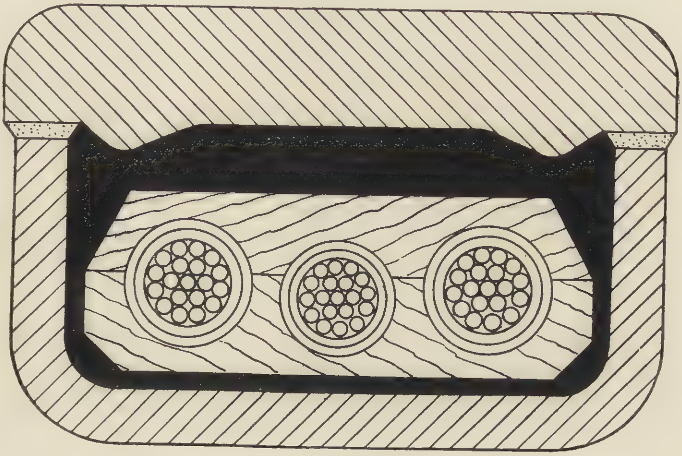


Fig. 342.

case the troughs are made with socketed ends, so that the lengths can be jointed up with cement.

Cast-iron troughs are also used, but they are more expensive than stoneware troughing, and the great drawback attending their employment is that the development of a "fault" rapidly leads to the establishment of a short circuit.

Fig. 343 shows some typical bridges for various troughs. Sufficient bitumen should be poured into the troughing to form a bottom layer, into which the bridges can be pressed at suitable intervals. The bridges will then adhere firmly, and the cables can be pulled along the grooves while they are being laid. After the cables have been filled in with bitumen, the covers can be cemented down.

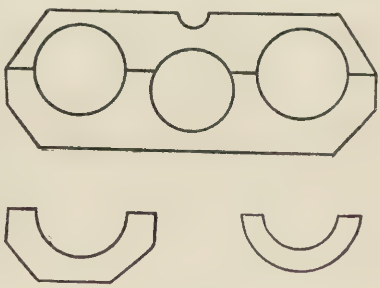


Fig. 343.

Fig. 344 illustrates the Howard solid system. In this there is an asphalt trough, on the bottom of which the cables are laid. Hot bitumen and then hot asphaltic concrete are poured over them, welding the whole into a solid mass. The troughing is cased in sheet-iron, so that it may not be damaged during trans-

port by rail or after delivery. For making bends, special lengths of troughing are supplied, from which the iron cases can be removed so that the troughs can be bent to any curve after warming. Jointing is effected by the use of a hot iron, the ends of the troughs being supported by a sheet-iron cradle during the process. This form of troughing occupies very little space, it is easily laid, it will yield to any ordinary pressure without cracking, and the material used is a good electrical insulator. Suitable joint-boxes are made for the Howard troughing in I, T, Y, and + shapes.

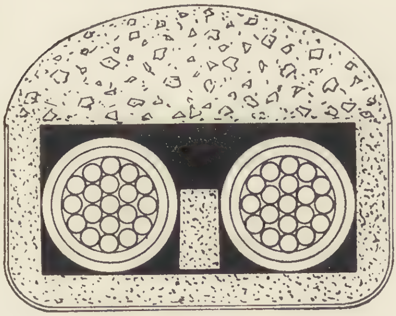


Fig. 344.

Troughing of any kind should be laid on a prepared foundation of rough concrete, and when passing under roadways a covering layer of concrete may be advisable as a protection against undue pressure.

Cables are sometimes laid directly in the ground, and although efforts are made to protect the cables by armouring, it is impossible to expect them to be durable. Steel armouring is readily corroded, and in a few years the insulating material will lose its original protection and may be expected to break down under destructive influences.

Earthing Device for Conduits and Cables.—Fig. 345 shows the Howard system, providing a safeguard against stoppage of supply when the insulation of a cable breaks down, and the elimination of damage by electrolytic currents. This figure represents a joint-box, connecting two lengths of lead-covered cable laid in the troughing. The cable is insulated from the joint-box by asphalt, and the lead covering of the cable is connected to earth through a resistance of 1 ohm and an indicating fuse to

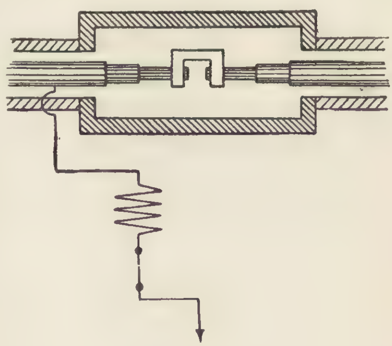


Fig. 345.

blow at 25 ampères. The lead covering of the cable is divided up into sections at the joint-boxes, and the only path from the lead covering to earth is through the resistance and the fuse. If a failure of the insulation occurs, the fuse is blown, the lead covering is insulated from earth by the asphalt troughing, and the resistance reduces the electrolytic current so that it is quite harmless. This method is obviously superior to the connection of the metal conduit or sheathing to a water main in the ordinary way.

Brick Chambers and Junction-Boxes.—In installations where several buildings are served from one source of supply, brick chambers are frequently desirable at main junctions and drawing-in points. The walls should be of brick set in cement and faced inside with cement; the floor should be of cement sloped to a trapped outlet which should be connected up to the nearest drain; and suitable provision should be made for ventilation.

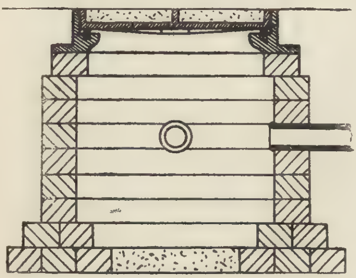


Fig. 346.

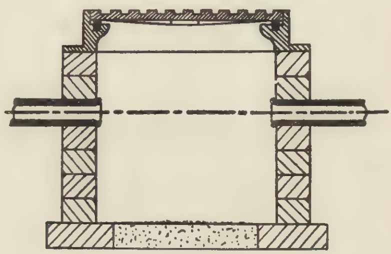


Fig. 347.

Fig. 346 represents a brick chamber for a main junction, and Fig. 347 a chamber for use as a drawing-in box or for straight-through joints.

The ends of the pipes or ducts should be fitted with wooden bushes to prevent the circulation of air, and the ends of the iron pipes should be connected across the brick chamber by a metal connection of electrical conductance equal to that of the pipe.

Fig. 348 is a sectional plan and elevation, showing the general construction and internal arrangements of a brick chamber designed as a house service box. The chamber projects above the ground level, and the front is fitted with a cast-iron frame and hinged door for access. In the figure are shown stoneware pipes through which a triple concentric cable is brought up from a solid system conduit, entering a junction-box from which separate cables are carried to plugs on three enamelled slate

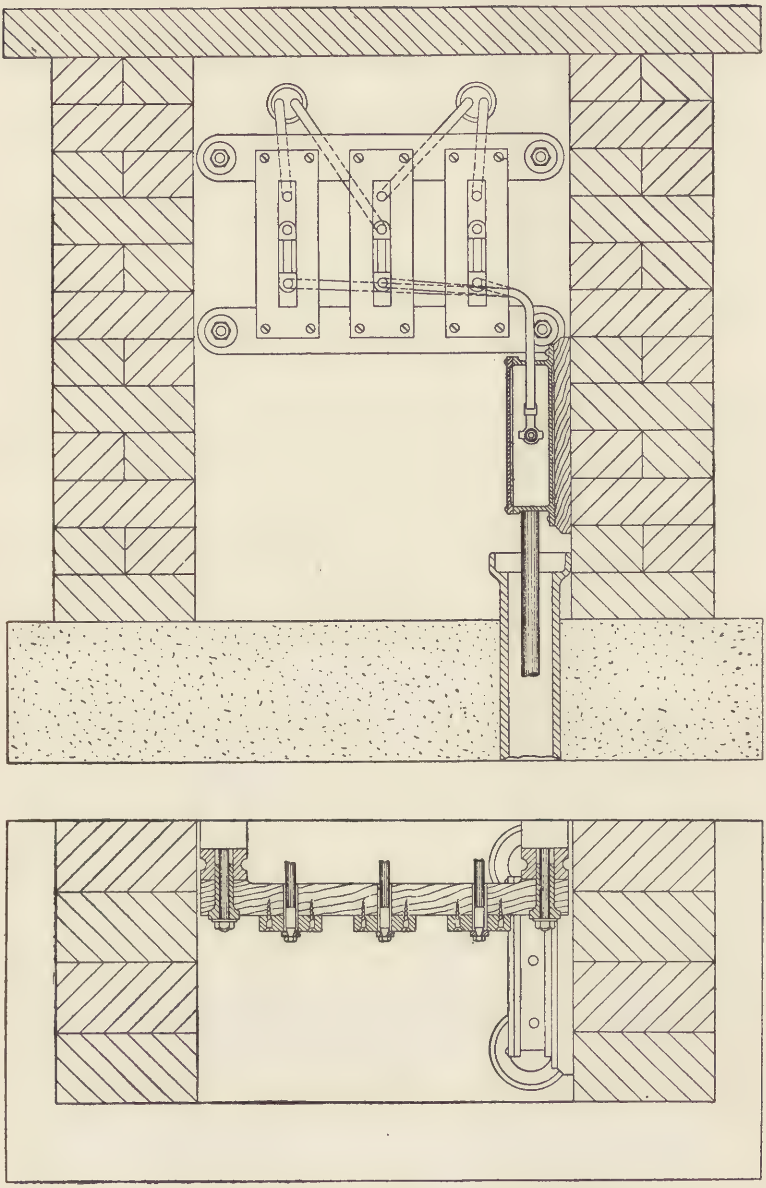


Fig. 348.

slabs secured to teak bearers bolted to fixing-blocks. Fuses are connected to the three plugs, and above these are other plugs

for the connection of two two-wire house circuits which enter stoneware pipes passing through the wall of the building.

Fig. 349 shows the details of a cast iron junction-box for the connection of two-wire house circuits with the outer and inner

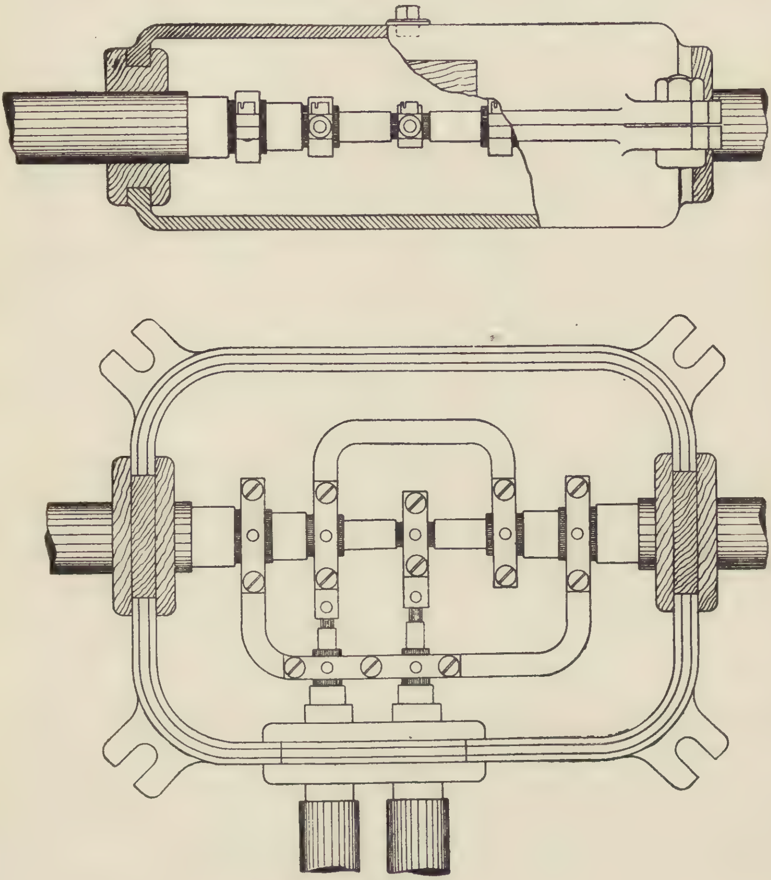


Fig. 349.

conductors of a triple-concentric main. In this case the house cable is of the concentric type. The "inner" is here the outermost of the three conductors of the triple concentric cable. The term "inner" merely applies to the theoretical position of the middle conductor in the three-wire system (see Fig. 336). A junction-box of this kind can be used without a brick chamber if desired.

Fig. 350 illustrates a trifurcating-box used for connecting three separate cables of a three-wire system with one triple-concentric cable, or *vice versa.*

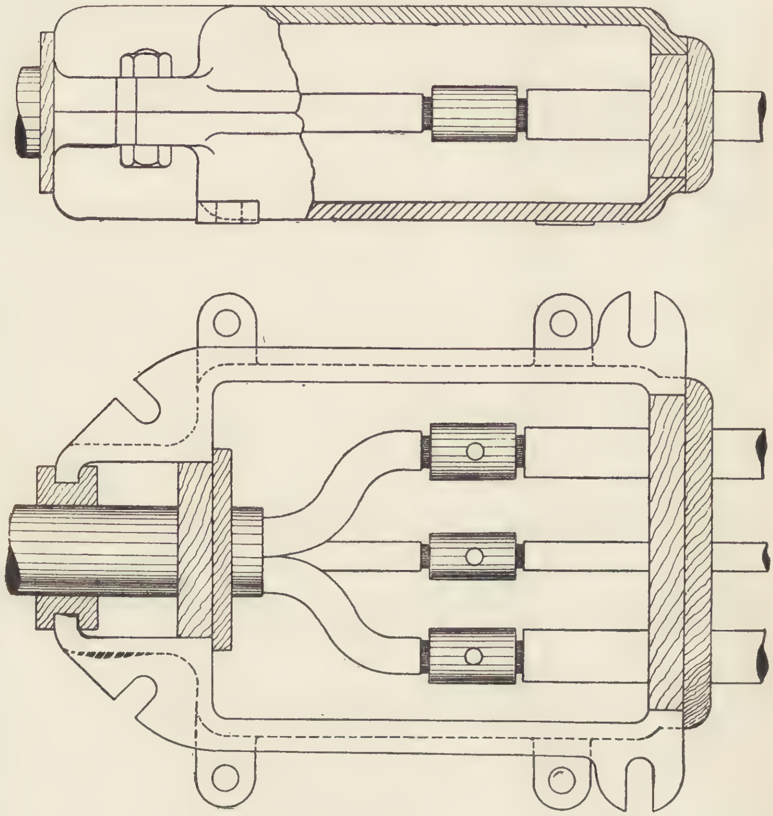


Fig. 350.

Fig. 351 represents a junction-box for connecting a two-wire concentric cable to two single cables, or *vice versa.*

Fig. 352 shows a *straight-through* junction-box, in which the two ends of the cable are joined by a gun-metal sleeve.

Junction-boxes for all the purposes incidental to cable laying are of the general construction here indicated. They are usually made of cast-iron, with lugs or flanges through which screws or bolts are used to secure the covers or to connect the two halves of "split" boxes.

The best way of protecting the cable joints inside the boxes is to fill the latter with bitumen through a pouring-hole. When

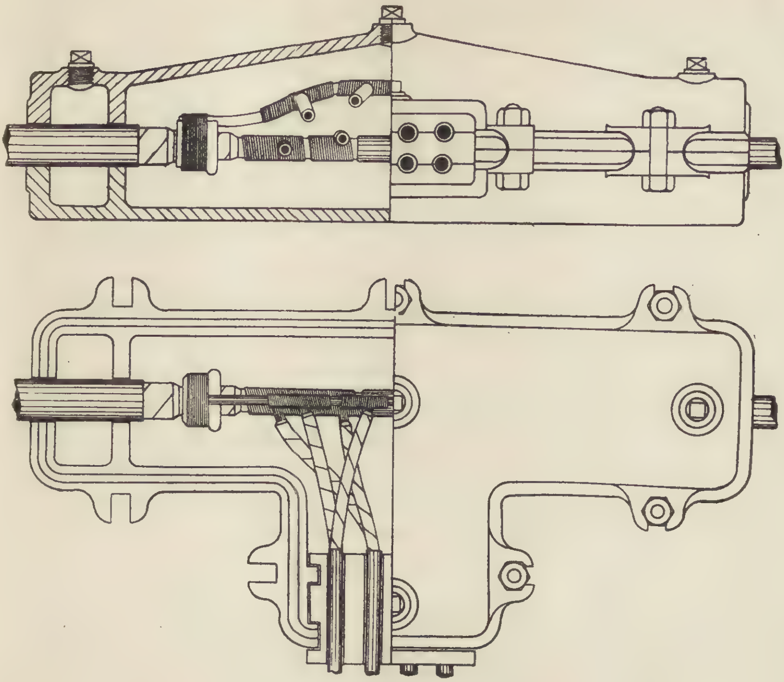


Fig 351.

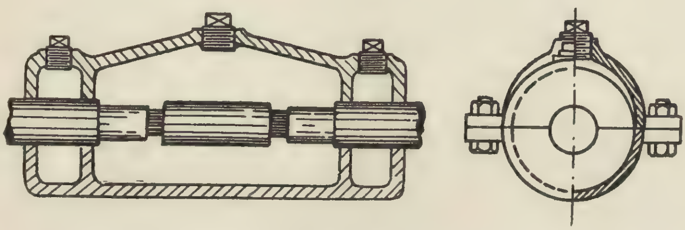


Fig. 352.

the boxes are not filled in this way, care must be taken to pack all the joints so that moisture may be kept out.

Several methods of leading cables into the boxes are adopted. For lead-covered cables, brass sleeves can be fitted, to which the lead covering is connected with a wiped joint. In most of the boxes illustrated above, the cables are led in through pockets which, as well as the main cavity, are filled in with bitumen.

Jointing.—In straight-through jointing, various methods are available, the first step in all of them being to remove the

covering and insulation of the cable for a sufficient distance. The first two of the following methods apply to the case of a seven-strand cable.

1. The wires are unstranded back to the insulation. The centre wire of each cable end is cut considerably shorter than the other wires, which are then wound round the middle wire as far as it extends, leaving six loose ends. The cable ends to be joined are butted together, and the six loose wires of each cable are wound round the newly stranded part of the opposite cable. The strands so made are tightened with pliers, and solder is sweated through the joint.

2. This also applies to a seven-strand cable. After being unstranded, the wires are cleaned, re-wound, and sweated together. The sweated cable ends are then scarfed, soldered together, bound with thin copper wire, and solder is sweated through the joint.

Joints in larger cables can be made by a combination of the two foregoing methods, as described below.

3. After unwinding the cable end, seven, nineteen or more of the inner wires are cut short, and soldered together to form a central core. The cable ends are then butted, and the outer wires are laid up round the cores, as they were round the centre wires in method 1.

4. Instead of butting the ends of the central core, as in 3, they can be scarfed and soldered together, the outer wires being coiled round the cores, as before explained.

5. A central strand is formed, as before, of several wires soldered together and butted. Alternate wires of each cable end are cut short, so that, after re-winding, a long wire at either end is jointed to a short wire at the other end. After soldering the wires, they are bound with fine copper wire and finally soldered.

6. The "telescopic" joint for the larger sized cables is formed by cutting back the outer wires of one cable end to form a spigot, and the inner wires of the other cable end to form a socket. After fitting the two parts together the joint is finished with binding wire and solder.

7. The ends of the copper are cut off square, and the wires sweated together. The ends are butted and soldered together; a piece of tinned copper sheet is then wrapped round the joint and the whole is well soldered. An opening is left in the copper sheet, through which solder can flow so that the joint may be

thoroughly well filled. Sometimes a gun-metal sleeve is used, as in Fig. 352, instead of the sheet copper.

When a fibrous cable has to be joined to a waterproof cable, clamps and copper strip connections are used, as in Fig. 353, and a junction-box becomes necessary.

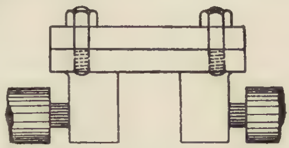


Fig. 353.

In attaching branch conductors to main cables, the T-joint may be adopted for small sizes. A large single-wire is bent to L-shape at the end, bound to the main with copper wire, and the joint is finished by soldering. Stranded cables are similarly treated, but the main cable is notched before binding and soldering the joint.

The Y-joint is better than the T-joint for large cables, as it avoids sharp bends. It is made like the T-joint except that the end of the branch conductor is bent through an angle of only 30 degrees. Figs. 354 and 355 show two forms of end-pieces

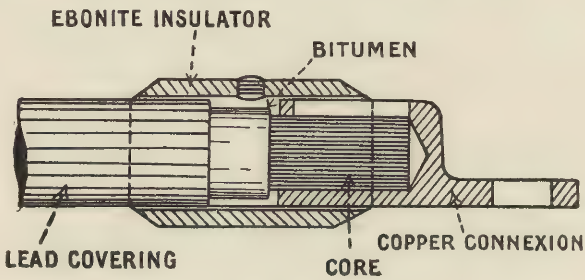


Fig. 354.

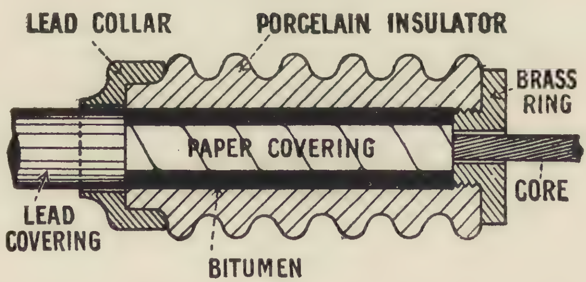


Fig. 355.

for connecting cables to any apparatus. These are intended to exclude moisture and to avoid risk of leakages.

Concentric Joints.—The outer conductor must be unstranded

and the wires bent back out of the way. The inner conductor is jointed in the usual manner and insulated. A sheet of tinned copper is then wrapped round the middle of the joint, the outer wires are laid over the copper and bound with copper wire, the joint is sweated, and the outer insulation and covering are made good. Care must be taken that the melted solder does not come in contact with the insulation.

Triple concentric joints are made in a similar way.

Practical Hints on Jointing.— Always keep the joint and the cable ends perfectly dry. Use a tent or tarpaulin for outdoor work in showery weather.

When a joint is once started, never leave it until quite finished.

To remove the lead covering from a cable end, cut round the metal at the required place, but do not cut it right through. Heat the cable end with a spirit-lamp, and bend it to and fro until the lead parts at the cut. When the lead is hot enough it can be pulled off quite easily. If a longitudinal cut should be necessary, take care not to damage the insulation beneath the lead.

Before jointing a lead-covered cable, cut a piece of pure lead pipe to form a sleeve about 3 ins. longer than the proposed joint, and large enough to slide over the lead covering. Dry the sleeve with a spirit-lamp, and slip it over the cable end after stripping off any outer tape or armouring, wrap up the ends of the sleeve with tape to keep moisture out, and join the cable ends in the usual manner. When the joint has been finished and insulated, draw the lead sleeve over it and solder up the two ends.

The solder used must not contain more than two parts of lead to one part of tin by weight, and in soldering the joints of cables nothing but resin or specially prepared soldering fluid should be used as a flux.

Insulating.—Before commencing to insulate any joint, smooth off all rough points of solder, remove burnt resin with benzoline, and see that the joint is quite clean.

Pure rubber insulation is made good after jointing by winding on pure rubber strip, stretching the strip as much as possible without breaking it, until the joint is a little thicker than the original cable. Stick down the ends of the strip with rubber solution, and cover the insulation with the same material. After

this covering coat has become "tacky," wind it round with rubber-covered tape and finish with shellac varnish.

Vulcanised rubber insulation can only be restored by the aid of a special vulcanising apparatus, called a "vulcanising cure." Most of the leading cable makers sell apparatus of this kind, accompanied with full directions for use.

Paper and fibre insulations are made good by white selvedge tape, boiled in resin oil. The tape is tightly lapped round the conductor, and the whole joint is immersed in a bath of hot resin oil. If this cannot be done, the resin bath is placed under the joint, and the hot oil is ladled over it until bubbles cease to be perceptible

HOUSE-SERVICE MAINS AND BRANCHES.

Whether the supply of current be derived from a public source or from a private generating plant, the arrangement of the house cables will be practically the same.

If several buildings have to be supplied from underground distributing mains, the house-service box, of which one type was illustrated in Fig. 348, affords the best means of connection.

If only one building has to be supplied, house cables can be run straight in from the street mains, or from the private generating station.

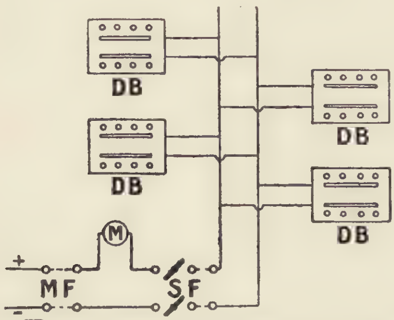
In either case the house cables must be protected by a main fuse, beyond which they should be led to a double-pole main switch and fuse, and then to one or more distribution boards, according to the nature of the system adopted.

When the current is obtained from a public source, the main fuse and the necessary length of cable are provided and connected up to the meter by the supply company or authority, by whom the meter is usually provided and fixed. All fittings and connections beyond the meter are provided by the consumer.

The main switch should be fixed as close as possible to the meter, and it is important that a fuse should be placed on each pole beyond the switch, as the fuses provided by public corporations are usually very large and therefore not likely to "blow" except in extreme cases.

General Arrangement of Circuits.—A simple method of arranging the mains is to carry a two-wire circuit to various

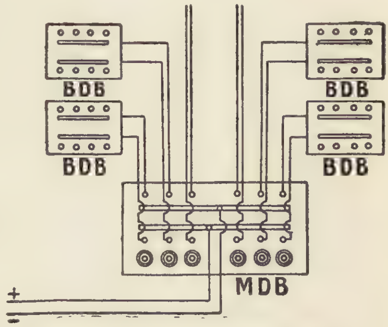
parts of the building, taking short branches to small distribution boards for the control of the branch circuits, as in Fig. 356.



MF = Main Fuse.
M = Meter.

SF = Main Switch & Fuse.
DB = Distribution Board.

Fig. 356.

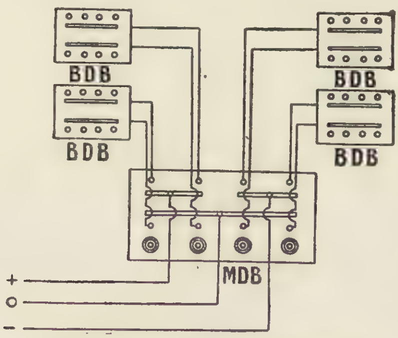


MDB = Main Distribution Board.
BDB = Branch Distribution Board.

Fig. 357.

A better method is to run each branch circuit from a main distribution board. Except in very small buildings, unnecessary expenditure would be incurred by running all the circuits directly from one distribution board, and in such cases the method shown in Fig. 357 should be adopted. This arrangement has the advantage that every circuit and sub-circuit can be controlled or tested independently of the others.

When current is brought into the building from a public supply station on the three-wire system, the house leads can be taken to a main distribution board, as in Fig. 358, from which two-wire circuits can be carried to sub-distribution boards. If the three-wire system is adopted in a private generating station for the supply of several buildings, the best plan is to take off two-wire circuits at house-service boxes, as shown in Fig. 348. These circuits can be dealt with by one or more distribution boards in the ordinary manner.



BDB = Branch Distribution Board.
MDB = Main Distribution Board.

Fig. 358.

Incandescent Lamp Circuits.—For incandescent lighting, lamps are generally arranged in circuits of eight 16 candle-power lamps

(= about 5 ampères), connected through double-pole fuses to the distribution board or boards. Each lamp is usually controlled by a single-pole switch, but it is sometimes convenient to arrange lamps in a group under the control of one switch.

A very useful arrangement for lamps in bedrooms, corridors, and staircases is shown in Fig. 359. The lamps here shown are controlled by either of the switches, which must be of the two-way type, designed so that contact is always made on one side or the other. One lamp can, of course, be treated in the same way.

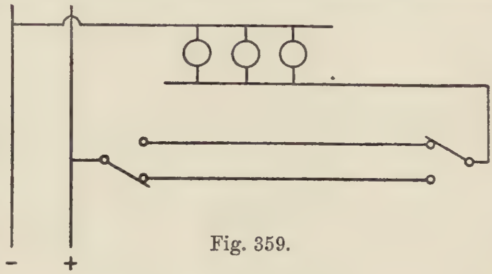


Fig. 359.

The system may be further extended so that in a long corridor the lamps may be controlled from either end or from any intermediate point, or that in a house of several floors the staircase lamps may be turned on or off from any floor.

Fig. 360 shows the arrangement of one Lundberg "intermediate" switch and two two-way switches for obtaining these results, and Fig. 361 shows a further extension of the system

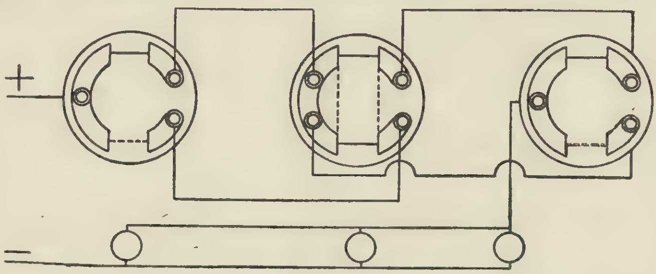


Fig. 360.

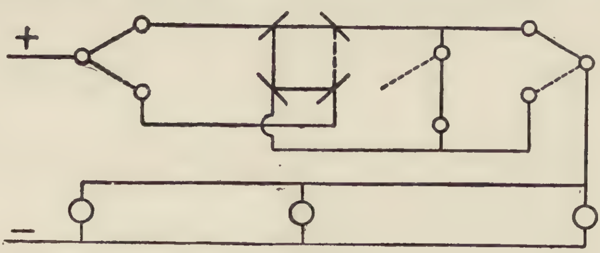


Fig. 361.

in which a "master" switch is inserted between the two + wires for preventing such control when desired.

Fig. 362 shows a further modification, where the substitution of a three-way switch at one end makes it possible to cut out of

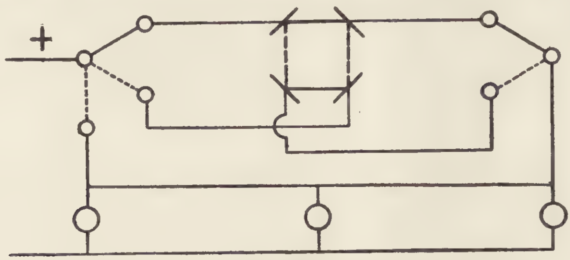


Fig. 362.

circuit all other switches at times when it is undesirable any lamps should be turned off at separate points.

If two incandescent lamps are supplied in *series* by one wire, the effect is the diminution of light to a mere glow of the filament. Such an effect can be intentionally produced by the Lundberg "dimming switch," as shown in Fig. 363. The switch is designed so that the two lamps can be placed in *parallel* or in *series*, or extinguished entirely, by turning the key to points indicated on the cover. The arrangement is very useful for bedrooms, corridors, and other places where a glimmer of light is desired during the evening or throughout the night.

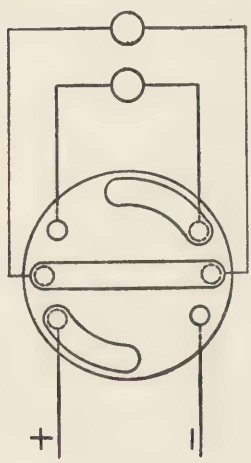


Fig. 363.

Arc Lamp Circuits.—With continuous current, two open arc lamps can be connected in series across a 100-110 volt circuit, or four lamps in series across a 200-220 volt circuit. On a 400-440 volt three-wire system, four lamps can be fitted in series between either outer wire and the inner wire, or eight lamps in series between the two outer wires.

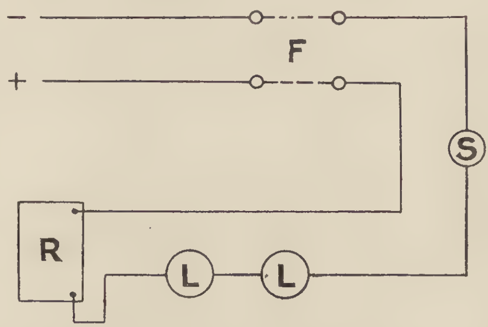
With alternating current, three open arc lamps can be placed in series across the conductors of a 100-110 volt circuit, and larger numbers in proportion to the voltage.

With continuous current, only one enclosed arc lamp can be connected across a 100-110 volt circuit, two across a 200-220

volt circuit; two between either outer and the inner of a 400-440 volt three-wire, or four across the two outers.

With alternating currents of 100-110 volts and 200-220 volts, the number of enclosed arc lamps connected in series is the same as with continuous current.

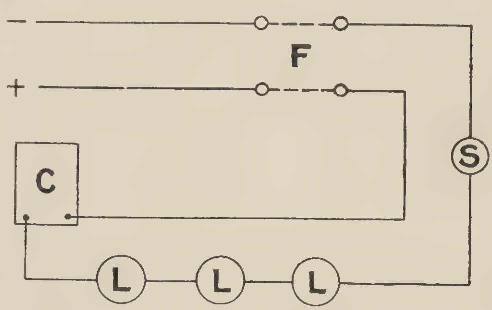
Figs. 364 and 365 show two simple arc lamp circuits for continuous and alternating current respectively.



F = Double pole fuse. | L = Lamp.
S = Switch. | R = Resistance.

Fig. 364.

Alternating Current.—The general arrangement of conductors and fuses on all circuits is practically the same for alternating as for continuous current; but if iron conduits be employed, both conductors should be placed in the same pipe to avoid induction effects, which cause loss of voltage when the conductors are in separate conduits.



F = Double pole fuse. | L = Lamp.
S = Switch. | C = Choking coil.

Fig. 365.

Sizes of Conductors Required. — To calculate the sizes of wires required in any building, a diagram should be made showing the estimated current in ampères and the total length of conductors in each circuit. The amount of current is usually calculated on the basis of 0·04 ampère per candle-power, but sufficient margin should be allowed for the addition of further lamps. The size of conductor in each part of the system can then be determined for any specified loss of potential by the rule given on p. 287. A very general practice is to select wires of size sufficient to keep down the loss of potential in a building to two and a half per cent per 100 yards of conductor. Table XVII.

will be found useful for calculations of this kind. Column 2 is calculated in accordance with the requirement frequently made that the current density shall not exceed 1,000 ampères per square inch, but even this density must be reduced on occasion to avoid excessive loss of potential.

TABLE XVII.—Wiring Table showing Capacity and Resistance of Conductors.

(Capacities are calculated on the basis of 1,000 ampères per sq. in., with a corresponding loss of 2·5 volts per 100 yds. of conductor.)

Size of Conductor.	Current in Ampères.	Standard Resistance at 600° Fahr.		
		Ohms per 1000 Yards.	Ohms per Mile.	Ohms per Kilometre.
18	1·8096	13·28	23·38	14·53
16	3·2170	7·478	13·16	8·178
14	5·0265	4·784	8·419	5·232
3/24	1·127	21·33	37·55	23·33
3/22	1·825	13·18	23·19	14·41
3/20	3·016	7·972	14·03	8·718
7/23	3·135	7·670	13·50	8·389
7/22	4·266	5·636	9·920	6·164
7/20	7·052	3·410	6·001	3·729
7/19	8·708	2·761	4·860	3·020
7/18	12·54	1·918	3·375	2·097
7/17	17·06	1·410	2·480	1·541
7/16	22·27	1·080	1·900	1·181
7/15	28·22	·8523	1·500	·9321
7/14	34·83	·6903	1·215	·7550
19/18	33·99	·7074	1·245	·7736
19/17	46·27	·5197	·9147	·5684
19/16	60·39	·3981	·7007	·4354
19/15	76·50	·3143	·5532	·3437
19/14	94·42	·2547	·4482	·2785
37/16	117·6	·2045	·3599	·2236
37/15	148·9	·1615	·2842	·1766
37/14	183·8	·1309	·2303	·1431
37/13	243·1	·09892	·1741	·1082
37/12	310·5	·07744	·1363	·08469
61/15	245·5	·09795	·1724	·1071
61/14	302·9	·07937	·1397	·08681
61/13	400·8	·06000	·1056	·06562
61/12	512·0	·04697	·08266	·05136

Jointing House Cables and Wires.—Small cables are jointed in the manner described on pp. 297-299.

To the directions there given we may add that conductors consisting of a single wire can be joined simply by twisting and soldering the ends. Joints cannot be altogether avoided, but the number should be minimised as far as possible by adopting the "loop" method of wiring described below.

Badly-made joints and imperfect making-good of the insulation are fruitful sources of after trouble, and no part of a lighting installation deserves more rigorous supervision than the jointing of conductors.

Methods of Wiring.—Positive wires are termed *leads* and negative wires *returns*. The correct positions for horizontal wires may be remembered by the wireman's rules:—

"Leads left" and "Returns right" for floors and ceilings.

"Leads low" and "Returns raised" for walls and partitions.

Leads are generally supplied in red insulation and returns in black insulation. This is of much assistance in wiring and testing.

Four methods of wiring lamp circuits for ten lights are shown in the following diagrams.

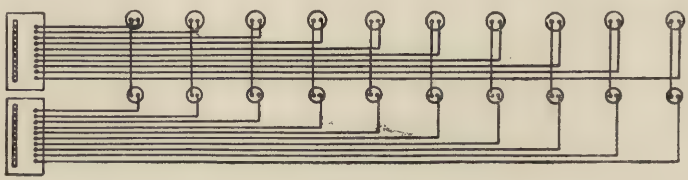


Fig. 366.

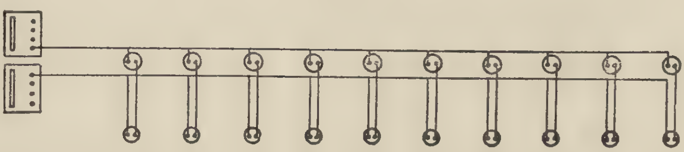


Fig. 367.

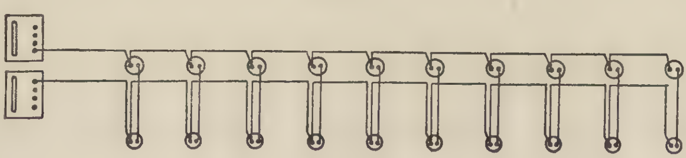


Fig. 368.

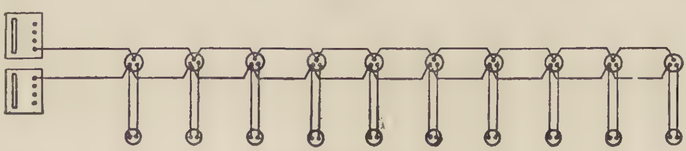


Fig. 369.

The "Distribution Board System," Fig. 366, involves the use

of a distinct lead and return for each lamp, the switches being on the distribution board.

The "Jointing System," Fig. 367, involves separate tappings for all conductors leading off to lamps and switches.

The "Loop System," Fig. 368, has one conductor looped-in to each lamp, and the other to the live terminal of each switch, with a connecting wire between the other terminal of the switch and the lamp.

The "Simplex Loop System," Fig. 369, is similar to the ordinary loop system, but instead of looping back the main wire to the switches, a single length of smaller wire is used for this connection.

Concentric Wiring.—There are several systems of concentric wiring, the details of which cannot be fully considered in this chapter.

In these systems both conductors are combined in one cable, and in most of them the *inner* conductor only is insulated; the *outer* conductor, which stands at very little above the earth potential, forming the earthed return and serving to protect the *inner* from injury. Sometimes a continuous metal tube is employed as the return, and the lead, consisting of an ordinary insulated conductor, is drawn into it. This method saves one wire.

Switches and fuses are placed on the insulated conductor, and as all these fittings must be of the single-pole type, further saving is effected. In fittings, only the lead is carried to the holders, the return being provided by the metal of the fitting, or by copper-braided cord. The lead is sufficiently insulated and protected throughout, and no shock can be received from the return, because it is purposely earthed at convenient points. No system is so safe as this, as any sparks or arcs must take place inside the outer conductor, and a fuse will blow if serious leakage should occur.

As metallic conduits are now used very largely for wiring, there is no reason why one ordinary wire and an electrically continuous tube should not be employed instead of two wires and a tubular conduit as hitherto adopted.

The system can be applied in connection with any private installation, but central station engineers using continuous current will not allow any installation *earthed* on one pole to be connected to their mains, owing to the risk of short circuits.

The same objection does not apply, however, in the case of alternating current.

An incidental advantage to be derived from concentric wiring is the prevention of electrically deposited dust on braided cords and on the bulbs of lamps. Braided cords not only collect dust but in turn project it against surrounding objects, often to the ruin of valuable wall decorations and upholstery. As these results are due to the action of the positive wire, a radical cure is effected by the use of concentric conductors with earthed returns outside.

Wood Casing.—In ordinary house wiring, wood casing is largely used for covering the conductors. Little protection is thereby afforded, and cases often occur in which the wires are injured by unforeseen moisture of the walls, or by nails driven through the casing. In perfectly dry situations where there is no risk of moisture or dampness of any kind, and where carpenters are not likely to fix woodwork or other persons to drive nails for pictures, casing may be adopted with safety. It must never be buried in plaster or cement.

Wood casing consists of two parts: a strip of wood with two or more grooves at sufficient distance for the isolation of leads and returns, and plain or moulded capping for covering the grooves after the conductors have been placed in position. American white-wood is largely used for casings, but oak, mahogany, walnut, and other woods are sometimes employed. Ornamental casings are made in great variety, so that wires may be covered in a pleasing manner. Fig. 370 is a section showing an unobtrusive mode of running wires to wall brackets by using a combined casing and picture moulding.

Fig. 370.

A coat of shellac varnish inside and outside helps to prevent the absorption of moisture by the casing, which should also be painted inside before use. It is very desirable to employ carpenters for fixing casing, as ordinary wiremen rarely understand the handling of carpenters' tools sufficiently to make a neat job, or the plugging of walls so as to ensure safety. The

grooved part of the casing is fixed in position first, the wires are then laid in place, and the capping is screwed on. Nails must never be used. Casing should always be of ample size to permit the wires to be drawn after the capping is fixed. Table XVIII. gives details of casing suitable for some generally used sizes of wire.

TABLE XVIII.—Size of Casing for various Conductors.

Conductors.		Casing.		
S.W.G.	Capacity in Ampères at 1000 per Square Inch.	Size of each Groove.	Distance between Grooves.	Width over all.
20	1·0179	$\frac{3}{16}$ in.	$\frac{3}{8}$ in.	$1\frac{1}{8}$ in.
3/22	1·825	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$1\frac{1}{2}$ in.
3/20	3·016	,,	,,	,,
7/23	3·135	,,	,,	,,
7/22	4·266	,,	,,	,,
7/21½	4·896	$\frac{5}{16}$ in.	$\frac{5}{8}$ in.	$1\frac{7}{8}$ in.
7/21	5·571	,,	,,	,,
7/20	·7·052	,,	,,	,,
7/19	8·708	,,	,,	,,
7/18	12·54	$\frac{3}{8}$ in.	$\frac{7}{8}$ in.	$2\frac{1}{4}$ in.
7/17	17·06	,,	,,	,,
7/16	22·27	$\frac{1}{2}$ in.	1 in.	$2\frac{3}{4}$ in.
7/15	28·22	,,	,,	,,
7/14	34·83	,,	,,	,,
19/20	19·12	,,	,,	,,
19/19	23·60	,,	,,	,,
19/18	33·99	,,	,,	,,
19/17	46·27	,,	,,	,,
19/16	60·39	$\frac{5}{8}$ in.	1 in.	3 in.
19/15	76·50	,,	,,	,,
19/14	94·42	$\frac{3}{4}$ in.	$1\frac{1}{8}$ in.	$3\frac{1}{2}$ in.
19/13	124·9	,,	,,	,,
37/16	117·6	$\frac{7}{8}$ in.	$1\frac{1}{4}$ in.	4 in.
37/15	148·9	,,	,,	,,
37/14	183·8	,,	,,	,,

Unless carrying very small currents, conductors of opposite polarity should never be placed in the same groove. It is generally permissible, however, to put two or more conductors of the same polarity in one large groove. This is termed "bunching" the conductors.

Metal Tube Conduits.—Tubes used as conduits are generally made of steel strip rolled to circular or oval form. When no

longitudinal joint is made between the edges of the steel, the tubes are commercially described as having a "close joint." Tubes of better quality have brazed joints and are made of heavier metal to afford adequate mechanical protection for the conductors. The tubes of light gauge have plain ends for socketed fittings, and the cylindrical tubes of heavier gauges are supplied with either plain or screwed ends for corresponding fittings. As a general rule, the tubes are enamelled inside and outside, but they are also supplied galvanised or lined with impervious insulating compound. They are also obtainable with an outer casing of brass for use in offices and rooms where it is desired to run wires from desk to desk or along the walls. Such tubes may take the place of picture rods if properly supported.

The oval form of tubular conduit is convenient for switch and other runs on the face of walls, especially when buried in plaster, as the chasing of brickwork is avoided in most cases, and the channeling of plaster is greatly reduced in depth.

Solid-drawn steel tubes are also used for wiring, a purpose for which they are in every way suitable, owing to their smooth interior finish. Ordinary gas barrel has been employed to some extent, but it should never be allowed, as its rough interior finish renders damage to the wires extremely likely. Welded or solid-drawn tube with screwed joints is always best. It makes a waterproof and watertight conduit, and the thickness of the metal required for screw cutting ensures adequate mechanical protection. Further, the screwed conduit is electrically continuous, and can be connected to "earth" at suitable points through water-pipes. In case of a leak, this connection prevents the formation of an arc in places where partial contact may exist with gas or water pipes. Earth connections must never be made to gas-pipes.

Moisture in conduits is a subject requiring the most serious consideration. Moisture percolates through walls and enters as vapour in the air. Absorbed moisture comes into direct contact with conduits embedded in mortar, and water condensed on walls and metallic conduits finds its way to joints, and thence into the conduits.

Bearing these things in mind, it is clear that open-seamed and socket-jointed tubes should never be buried in outside walls.

Watertight conduit is very desirable on "sweaty" walls, under plaster or stone flags, and in draughty places; and conduit with insulated lining is always advantageous, as it is less affected than bare or enamelled tubing by changes of temperature.

The question of water in conduits receives too little attention from electrical fitters, and consumers do not realise the fact that presence of water on a conductor may cause a fire. Drip pipes should certainly be provided for conduits much as they are for a system of steam pipes.

The following table gives the wiring capacity of "Simplex" tubular conduits for some generally used sizes of conductors:—

TABLE XIX.—Wiring Capacity of Simplex Conduits.

(The numbers refer to conductors "threaded" through the tubes. If "drawn" through, one size larger tube must be taken in each case.)

Size of Conductors.	Size of Conduits and No. of Conductors.															
	½″		⅝″		¾″		⅞″		1″		1¼″		1½″		2″	
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
18	2	1	4	3	6	3	8	5	10	7	...	...	...	...	...	...
16	2	1	3	2	4	3	7	4	8	6	12	9	...	...	...	...
3/22	3	1	4	3	5	3	7	5	11	7	15	10	...	...	...	...
3/20	2	1	4	2	5	3	7	4	10	6	13	9	...	...	...	...
3/18	1	1	2	1	3	2	4	3	5	4	7	6	...	...	...	...
7/20	1	1	2	1	3	1	4	2	6	4	9	5	15	10	...	...
7/18	1	...	1	...	1	1	3	2	4	3	6	4	9	7	...	...
7/16	...	...	1	...	1	1	1	1	2	2	4	3	5	3	10	8
7/14	...	...	...	...	1	...	1	...	1	1	2	1	4	2	8	6
19/18	...	...	...	...	1	...	1	...	1	1	2	1	4	2	8	6
19/16	...	...	...	...	...	...	1	...	1	...	1	1	3	1	4	4
19/14	...	...	...	...	...	...	...	...	...	...	1	1	1	1	3	2
37/16	...	...	...	...	...	...	...	...	...	...	1	...	1	...	1	1

L = Light Conduit. H = Heavy Conduit.

Makers of tubular conduit supply tube fittings of every necessary kind for the complete wiring of a building, and such special tools as may be required in connection with tubular methods of wiring. As the different varieties of fittings and accessories are to be counted by hundreds, it would be impossible to mention them in detail. Brief reference to some of them is made incidentally in the following notes.

As far as possible let all conduits follow a straight course, with easy pipe bends. Use fittings with inspection covers,

except in short and straight runs, and insert junction boxes or drawing-in boxes at all places where trouble is likely to be experienced in drawing the wires through. In places where future extensions may be probable, fit junction boxes with one or more plugged outlets. After cutting a tube be careful to smooth the edges.

Tubes up to $\frac{3}{4}$ in. diameter can be bent cold, but care must be taken not to injure the enamel, or to alter the shape of the tube. Make offsets in pipe lines of more than $\frac{3}{4}$ ins. diameter, by using suitable fittings. Always take care that socket joints are pushed securely home, or the tubes may come apart when drawing the wires.

Provide steel "draw-in" or "fish" wires in all conduits, and see that it will not be necessary to draw the wire through more than two or three bends without having access to a drawing-in box.

When drawing in the wires, always use a detachable drawing-in piece and sufficient French chalk.

Wires are frequently "threaded" simultaneously with the erection of the conduits. This saves much expense, but may lead to trouble. Threading is only practicable in tubes with slip or socket joints, as the making of a screwed joint would twist the wire so much that the time occupied in straightening it would counterbalance any saving. When wires are threaded, careless workmen sometimes join small lengths of wire together to reach through a conduit, and otherwise do their work so that the wires cannot be withdrawn in case of a breakdown.

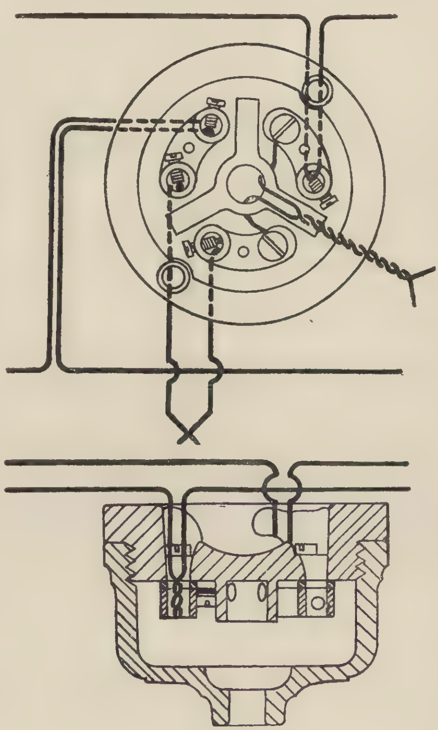


Fig. 371.

It is permissible to place the positive and negative con-

ductors in the same tube, although this may not be done with wood casing.

Fig. 371 illustrates the Douglas patent three-contact ceiling rose, for use in connection with the Simplex method of loop wiring.

At any joint where a pendant is to be supplied from a conduit in which there are several wires, a special pendant-fitting box should be used, so designed that straight-through wires may pass through a porcelain bridge, Fig. 372, while the wires serving the point are led outside the bridge and connected to the contacts shown in the figure. In this way the braiding of other wires is kept away from live contacts.

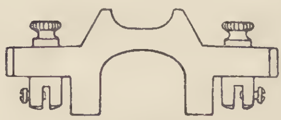


Fig. 372.

ELECTRICAL ACCESSORIES.

The following notes are intentionally brief, as instruments and fittings coming under this head are so numerous that no attempt at detailed description could be satisfactory in a chapter such as the present. Fully illustrated catalogues can be obtained from which suitable selections can easily be made.

Fuses or "Cut-Outs."—Fuses may be of copper, lead, or tin, but alloys of tin and lead are generally used. Fuse wires are fixed so as to form part of the conductors in a circuit, and their sectional area should be such that the metal will melt, if the current raises the temperature of the conductor by 18 degrees Fahr., or when 50 per cent more than the calculated current is passing along the conductors. The fuse has then "blown," and the circuit is "cut out." Fig. 373 shows a largely used form of fuse wire.

Fig. 373.

A double-pole fuse must be fixed at every point where any conductor is connected with another conductor of larger size, and if the pressure exceeds 125 volts two single-pole fuses must be provided. In modern practice the fuses are grouped together as far as possible on boards, fixed in convenient positions where they can be examined and repaired. The distribution boards previously mentioned are really fuse boards with the addition of switches. It is not easy to determine the area of a fuse plate or

wire by calculation, as results are affected by temperature, length of conductor, size of fuse terminals, and contact surface.

Makers supply fuses suitable for currents from 5 to 100 ampères, and as the melting currents are determined experimentally before the fuses are delivered, reliance may generally be placed on the efficiency of the fuses within reasonable limits.

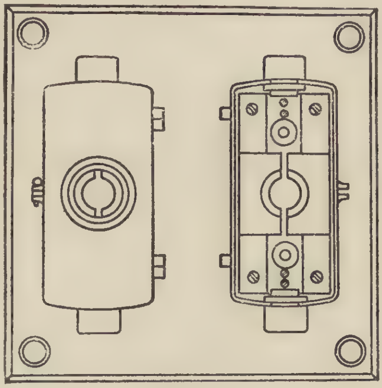


Fig. 374.

Fig. 374 shows two single-pole main fuses, for circuits up to 250 volts, each fuse being enclosed in a cast-iron case and mounted on a teak base with insulated fixing holes. One of the hinged covers is removed to show the internal arrangement.

Fuse Boards and Distribution Boards.—A typical fuse board is illustrated in Fig. 375. This comprises two enamelled slate slabs, on each of which is fixed an *omnibus bar,* often called a *bus bar,* each having a terminal at the side for the main cable. Four pairs of terminals with milled screw heads are provided for the attachment of fuse wires or fuses, as Fig. 373. The

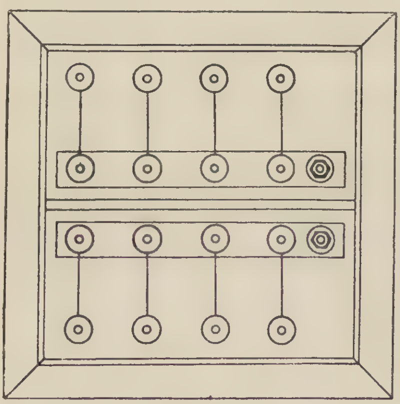


Fig. 375.

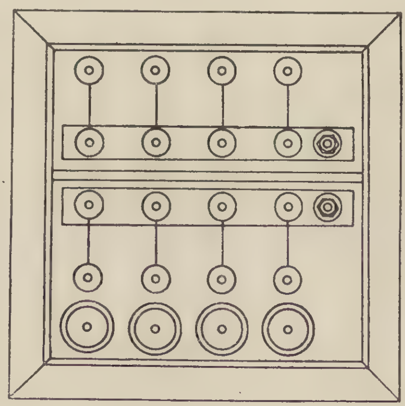


Fig. 376.

slate slabs are separated by an insulating fillet to prevent leakage through the slate from one pole to the other. The board is enclosed in a teak case with glass door, lock, and key.

Instead of milled-head fuse terminals, fibre or china spring-clip fuse-holders can be fitted, and the boards are made up to suit any required number of circuits.

A typical distribution board is illustrated in Fig. 376. It will be seen that this is similar to a fuse board, with the addition of switches controlling the four circuits. This board can be provided with milled-head or spring-clip terminals, as desired.

Fuse boards and distribution boards are also made in iron cases with pipe outlets for the connection of iron conduits for cables and wires.

Switches.—A double-pole house-service main switch with

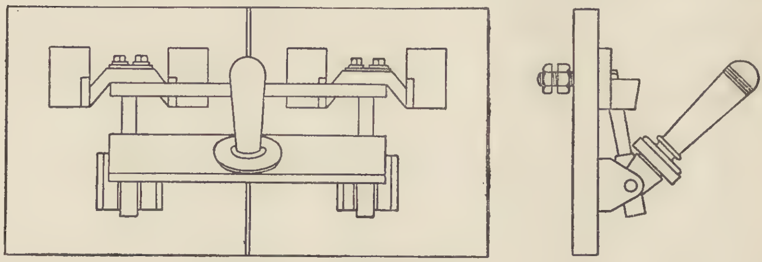
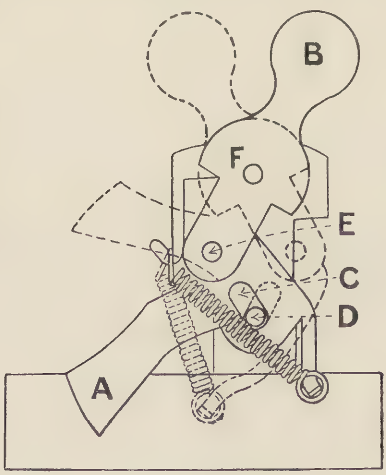


Fig. 377

fuse terminals is illustrated in Fig. 377. This is of the G.E.C. type, and is suitable for circuits up to 250 volts.



A = Contact arm.
B = Actuating knob.
C = Slot giving variable leverage.
D = Fixed pin on which A rocks.
E = Movable pin connecting A and B.
F = Fixed pin on which B rocks.
The broken outlines represent the "off" position.

Fig. 378.

Switches for controlling single lamps or small groups of lamps

are generally of the single-pole type. Such switches are made in great variety, and no difficulty should be experienced in complying with any requirements. Whatever type of switch be used, it is always necessary that it should be large enough to carry the current required without overheating. For 200 volt circuits the switch contacts should be separated by a china wall to prevent sparking, the break should be both quick and long, and the cover should be of china. Fig. 378 shows the mechanism of the "Pivot" tumbler switch, with a capacity of 5 ampères at 200 volts.

Special watertight switches should always be employed for damp or wet positions. These are made with cast-iron cases, having securely jointed covers and brass glands for the leading-in wires.

Various forms of switches for special purposes are also made, some of which have been mentioned under the head of Incandescent Lamp Circuits.

Ceiling Roses—Wall Plugs—Floor Plugs.—Ceiling roses are used for the purpose of connecting the flexible cords of fittings with the conductors. They are generally made with china bases and covers, and are supplied suitably for either the jointing or the looping system of wiring.

Wall and floor sockets and plugs are very convenient for the attachment of portable lamps, and are provided in numerous patterns, suitable for connections of all kinds in private houses, public buildings, and business premises.

Lampholders.—Lampholders are intended for the establishment of a connection between the conductors and the lamps in such a way as to permit the lamp to be fixed or removed easily. Lampholders must be chosen of patterns suitable for the fittings to be used. They should neither be so large as to spoil the appearance of the fittings, nor so small as to interfere with wiring. When used for pendants, good cord grips are essential, so that no weight may be carried by the terminals. Lampholders are made in many different patterns suitable for direct attachment to walls, ceilings, and electroliers. As nearly all incandescent lamps have bayonet ends, the holders are usually provided with bayonet sockets, but other patterns are obtainable for special forms of lamp.

Pendants and Brackets.—Electric-light fittings are generally wired by the makers, but this work is not always done so well

as it should be. If brackets are wired on the site of the works, the wires should be taken right through to the lampholders without jointing.

When gas-fittings have been adapted for electric light, they must be properly insulated from the supply pipes. Fittings intended for both gas and electric light should never be used.

All electric light fittings must be carefully insulated.

Wood Blocks.—Wood blocks are invariably used for the fixing and insulation of wall-brackets, electroliers, ceiling roses, wall connections, and switches. These are supplied of round or square shape in the following stock sizes:—$2\frac{1}{2}$ in., 3 in., $3\frac{1}{2}$ in., 4 in., and 5 in. diameter or side of square. Fig. 379 shows the usual recesses for circular blocks. Rectangular blocks are sometimes convenient for the fixing of two or more switches, as in Fig. 380.

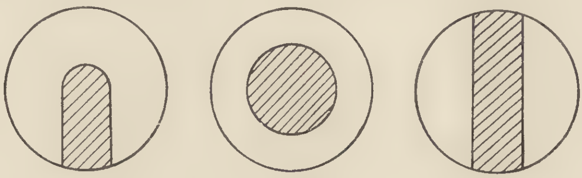


Fig. 379.

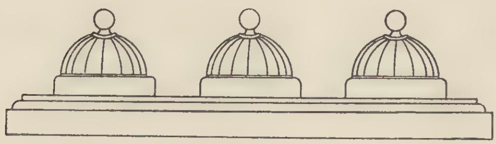


Fig. 380.

In some walls it is a good plan to build-in hardwood bricks, to provide adequate fixing for heavy brackets or other fittings.

Meters.—Meters are usually provided and kept in order by supply corporations, and it is not necessary to give particulars of the various types manufactured.

The following is an extract from the rules of the London County Council as to the testing of electricity meters.

FEES FOR TESTING SINGLE METERS OF ANY DESCRIPTION.

0 – 50 ampères capacity	. . . . . .	£0	10	0
50 – 100 ,,	. . . . . .	1	0	0
100 – 200 ,,	. . . . . .	1	5	0
200 – 400 ,,	. . . . . .	1	10	0

The above fees apply to meters tested at the Testing Station of the Council—42 Cranbourne Street, London, W.

For examining in position after fixing and certifying if found correct, any single meter (which has already been tested for accuracy at the Council's Testing Station) within a radius of three miles from Cranbourne Street, 2s. 6d.; Do., any distance from three to six miles, 3s. 6d.

Testing.—Cables are always tested by the makers before delivery, but it is wise to make a further test before laying them in underground conduits.

House wiring should be tested for continuity during progress of the work. This is easily performed by a wireman's testing set, but the information so obtained does not prove that the wires are free from injury or bad joints.

Three tests of the wiring should be made when work is completed, under twice the working pressure.

1. Wire to wire insulation test.
2. Insulation resistance.
3. Drop of potential.

Of these, the two first tests are conducted before the wiring system is connected up to the service mains.

The first test is made with the switches and fuses on, the lamps are removed from the holders, and the testing apparatus is connected between the two poles of the installation.

The second test is made with all lamps in position, and the testing apparatus is connected between any convenient point of the installation and "earth," the insulation resistance generally adopted being 75 lamps = 1 megohm. Evershed's ohmmeter and the Silvertown testing set are largely used for insulation tests.

The third test is made after the system has been connected with the source of supply, and is performed by connecting a voltmeter between the house terminals, and then in succession between the terminals of the most distant lamp connection in each circuit.

Cost of Wiring.—The cost of wiring a building depends very much upon the locality, upon its distance from the workshop of the contractor, and upon other circumstances which necessarily vary from case to case.

In a general way, the actual cost to the contractor of wiring per "point" in an ordinary dwelling-house of average size, if the best materials are used, is not less than the following, with wood casing and metal conduit respectively:—

	A	B
Cable, wire, and flexible cord	£0 5 6	£0 5 6
Metal conduit and fittings	...	0 8 0
Wood casing	0 1 6	...
Switches	0 1 6	0 1 6
Ceiling roses	0 0 6	0 0 6
Lampholders	0 0 6	0 0 6
Wood blocks and sundries	0 0 6	0 0 6
Labour and incidentals	0 10 0	0 7 6
	£1 0 0	£1 4 0

These figures are exclusive of providing and fixing main switch and fuse, main and branch distribution boards, fuse boards, lamps, lamp-shades, electroliers, and brackets.

In addition to the actual cost, the contractor has to provide for supervision, fares, and general trading expenses, and again for profit. Hence it will be seen that perfectly reasonable prices would be about 30s. per point for class A, and 35s. per point for class B.

For country work, the price per point would be higher, owing to the cost of freight and travelling expenses, and to the fact that "country money" is expected by men working away from home.

From the foregoing figures it must be clear that offers such as are sometimes made to carry out wiring at rates of 10s. to 15s. per point should be closely inquired into before acceptance. For the purpose of ensuring good work and of avoiding misunderstanding, a clearly worded specification should be prepared, and care should be taken to stipulate exactly what materials and fittings are to be included in estimated items. The specification should also define the quality of materials, and say whether or not the contractor is to provide for cutting away and making good, painting, varnishing, and decorative work, taking up floor-boards and carpets, shifting furniture, removing gas-fittings, and plugging off gas-pipes.

The contractor should further be required to satisfy the requirements of the insurance company, to complete the work to the entire satisfaction of the architect or his consulting engineer, and to maintain the installation for a period of twelve months after completion.

Wiring Rules.—The various sets of wiring rules and regulations issued by insurance companies and electricity supply authorities are so numerous that they cannot be mentioned in detail. Standardisation of wiring regulations is much to be desired, and it is to be hoped that the rules prepared by the

Institution of Electrical Engineers will ultimately be accepted by the companies and authorities concerned.

The rules of the Institution of Electrical Engineers, as revised in 1903, are printed in Appendix II., p. 376.

ELECTRIC BELLS, SIGNALS, AND TELEPHONES.

Batteries and Conductors.—Either *Leclanché cells* or *dry cells* are used for the batteries of bell, signal, and telephone circuits. Full directions for the use of the various forms of Leclanché and dry cells are furnished by the respective makers and need not be given here. The E.M.F. of all primary batteries may be taken at the average of 1·5 volts.

The number and size of the cells required for bell or telephone installations depend on the duty required. For ordinary house systems two or three No. 2 size cells will usually be sufficient. The general rules to be remembered are that the size of the cells must be proportionate to the current required, and the number of cells must be proportionate to the voltage required. So far as general principles are concerned, the method of wiring bell and kindred circuits is similar to that adopted in electric lighting, but with a considerable relaxation of attendant precautions.

Leclanché-Barbier Cells.—Fig. 381 is a section of the Leclanché-Barbier cell, in which the carbon agglomerate is in the form of a cylinder, composed of plumbago and manganese peroxide. Round the top of the cylinder is a metal collar, and a binding-screw is the positive terminal of the cell. The collar supports the agglomerate in the glass jar, and an indiarubber washer makes a tight joint. The zinc rod, the upper end of which is the negative terminal, passes through a block of paraffined wood, closing the top of the agglomerate cylinder, and the bottom of the zinc rod is insulated with a piece of indiarubber tube. Small holes are provided in the cylinder to facilitate circulation of the saline solution between the inside and the outside of the cylinder.

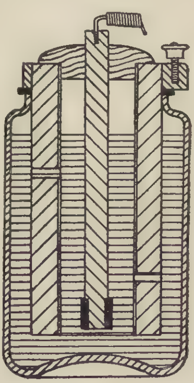


Fig. 381.

Burnley or E.C.C. Dry Cells.—Fig. 382 shows the E.C.C. dry cell, which consists of a carbon rod set in the midst of a paste composed of powdered carbon and manganese peroxide, moistened

with a solution of ammonium and zinc chlorides. The outer layer of paste consists of calcium sulphate and flour moistened with a solution of ammonium and zinc chlorides. The zinc case is in immediate contact with the paste, and is sealed at the top with bituminous compound, through which passes the tube permitting the escape of gas. The cell is insulated by being enclosed in a stout millboard case.

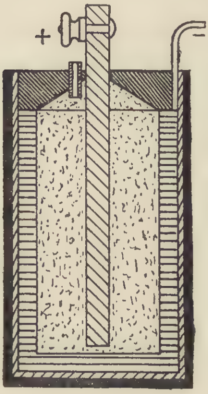


Fig. 382.

Conductors.—For outdoor purposes the following classes of wire are available :—

Bare copper, or *phosphor bronze, wire* carried on insulators fixed on buildings or posts.

Vulcanised rubber wire of tinned copper, insulated with pure and vulcanised rubber, taped, braided, and covered with preservative compound.

Lead-covered wire of tinned copper, insulated with pure and vulcanised rubber and rubber-coated tape; the whole vulcanised together, treated with preservative compound, and lead-covered. This type is intended for underground work.

For indoor use the following are the chief classes of wire :—

Paraffined wire of copper, double cotton covered and paraffined. This is only suitable for dry situations.

Asphalt-insulated wire of tinned copper, insulated with asphaltic compound and tarred flax wrapping, cotton braided and paraffined.

Parchment-insulated wire of copper, insulated with patent parchment.

Pure rubber-insulated wire—(*a*) of tinned copper, pure rubber insulation, cotton stranded and lapped, and paraffined; (*b*) of tinned copper, one coat of cotton, one lap pure rubber covered with felt tape, braided and coated with preservative compound.

Gutta-percha-insulated wire of tinned copper, covered with pure gutta-percha and cotton braiding. This is expensive, and does not wear particularly well.

In addition to the above, silk and cotton covered flexible cords are made for use with movable or suspension pushes, and there are different kinds of parallel and twisted twin wires, and multiple cable for inside and outside work.

Bell, telephone, and similar wires for inside work are generally

of No. 18 or No. 20 gauge, but concealed wires ought never to be smaller than No. 18 gauge.

Conduits and Fittings.—For underground work, lead-covered wires may be laid directly in the ground, but it is better to run the wires in an iron pipe or wooden box to guard against accidental injury. In cases where bell or telephone wires are being laid simultaneously with electric light cables, the wires can be placed in the stoneware or other conduits provided for the cables, thus affording adequate protection without additional cost.

In the basements of buildings and in damp situations, twin lead-covered or insulated wire should be used, and drawn into composition pipes or steel-tube conduits.

For the outside walls of buildings, lead-covered wire may be fixed without protection, or ordinary wire may be drawn into tubular conduits, or bare wire can be carried on insulators.

In new buildings, tubes are generally provided and fixed during the erection of the building. Zinc tubes are largely employed as conduits in this way, but thin steel tubes cost little more and afford much better protection against nails. As far as possible, outer walls should be avoided for bell and telephone wires, but when they must be used, iron or steel tubes should always be employed. When wires are run in tubes of any kind, a wrapping of tape will be found useful for protecting the insulation from injury by the ends of the tubes. The tubes should terminate in wood blocks plastered into the walls, these blocks serving for the attachment of bell-pushes or other connections.

For surface work in dry situations paraffined wires may be used and secured by tinned staples. Fig. 383 shows an improved

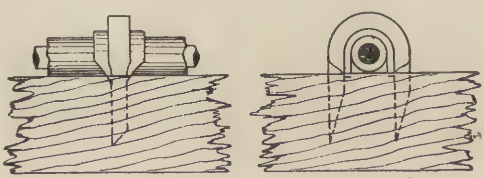


Fig. 383.

insulating staple. When several wires are bunched, wooden cleats or continuous casing must be employed.

Wires under floor-boards may be run in notches cut in the joists or through holes bored in the joists.

When a connection is brought into a building from bare

overhead wires, it is finished on an insulator, and insulated leading-in wires are carried to wall terminals mounted on wooden blocks.

Fig. 384 shows a simple form of lightning arrester for use in connection with bare wires. This may be fixed on the wall terminal board, whence a wire is connected to earth, or it can be fixed on an intermediate wall block. In the figure the two serrated bars are separated by a small air gap, the line is connected to the upper bar, and the earth wire to the lower bar. The lightning effect discharges itself to earth, and thus the instruments on the line are protected against excessive potential.

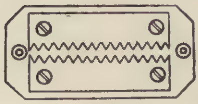


Fig. 384.

ELECTRIC BELLS AND SIGNALS.

Bells and Indicators.—An ordinary electric bell, Fig. 385, is essentially a vibrating contact-breaker carrying a small hammer on its spring, the hammer striking a gong. A continuous action vibratory bell, Fig. 386, is fitted with a device to keep the bell

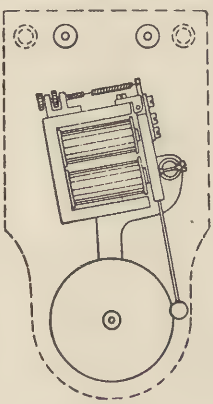


Fig. 385.

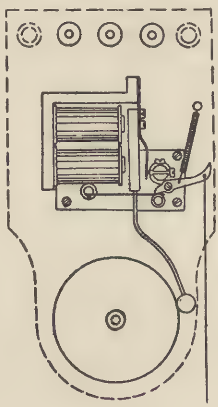


Fig. 386.

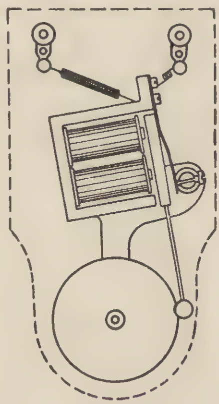


Fig. 387.

ringing when once the circuit has been made. The circuit is broken by pulling down the lever at the right-hand side.

A single-stroke bell, Fig. 387, is simply a gong, an electro-magnet, and an armature with a hammer at the end arranged to strike the gong when the armature is attracted by the magnet.

Gongs of different shapes and tones, wire gongs, buzzers, and

trumpets, are frequently applied for signalling purposes instead of ordinary bells. Sets of two or more bells, each of different tone and mounted on one board, are sometimes convenient for enabling servants or attendants to recognise by sound the room from which a bell has been rung. Slow-striking bell-mouthed gongs, struck every two seconds, give a pleasant change from the ordinary action and sound. Fig. 388 illustrates a handsome form of bell for a large house. Water-tight bells with cast-iron cases will be found useful for stables and other outbuildings.

Fig. 388.

Indicators are necessary when bell-pushes in different rooms act upon one gong. These useful accessories are made in numerous types and in infinite variety to suit all possible requirements.

Electric Fire Alarms.—In every dwelling-house of more than average size, and in all public institutions, office buildings, and

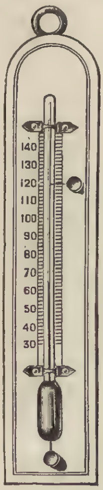


Fig. 389.

Fig. 390.

Fig. 391.

warehouses, the adoption of an automatic fire-alarm system is a most desirable safeguard. The operation of a fire-alarm bell is

effected by means of a *thermostat*. In Fig. 389 the thermostat consists of an ordinary mercurial thermometer with a platinum wire fused into the tube so that the rising column of mercury will make contact for closing the circuit at any required temperature. In Fig. 390 the thermostat is operated by the expansion of air in a sealed chamber, causing one side to bulge upwards until contact is made with the set-screw at the top of the instrument. This is the most reliable form, as all contact points are under cover. In Fig. 391 the thermostat operates by the unequal expansion of two metals under the influence of heat.

It is only necessary that the thermostats should be fixed near the ceilings of the apartments to be protected and connected by suitable circuits to an alarm bell of adequate size, fixed in a place where it cannot fail to be heard. The temperature at which an alarm will be given can be regulated when fixing the apparatus.

Burglar Alarms, and Door Openers.—Various patterns of contacts for doors, windows, letter-boxes, curtains, and blinds are available, so that an electric alarm bell may be rung if any person should attempt to gain access to a house. Electric door openers are very useful for enabling door, garden, lodge, and other gates to be opened from a distance. These devices can be fitted quite easily on a bell or telephone circuit, or separately, as desired.

Water-Level Indicator.—This appliance consists of a contact-box, to be fitted on a tank, combined with a float and counter-weight. The level of water is shown by an indicating dial fixed in any convenient position in the lower part of the building, and if desired an alarm bell can be rung at "full" and "empty." For country houses or other buildings where storage tanks are used this is a very useful apparatus.

Wiring.—The following diagrams show some of the simplest modes of wiring bells and indicators. Fig. 392 is an ordinary

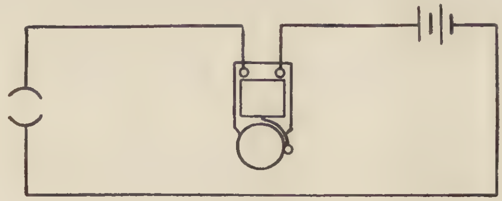


Fig. 392.

single-bell circuit, and Fig. 393 is a single-bell circuit with earth

return. The latter possesses no advantages for inside wiring, but saves one outside wire in communications from one building to another. The earth connection at each end can be made by a soldered joint to water or gas pipes. If a good earth cannot be obtained by means of some convenient pipe, it is better to use a return wire, as in domestic installations this is generally cheaper

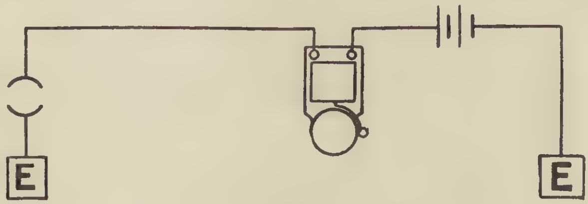


Fig. 393.

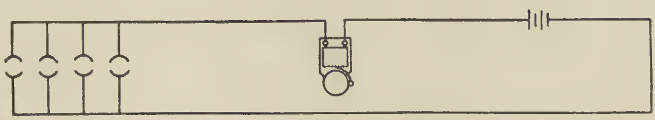


Fig. 394.

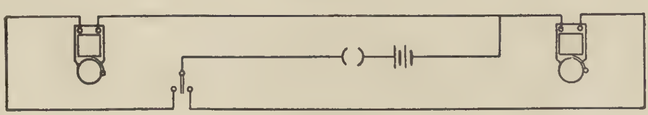


Fig. 395.

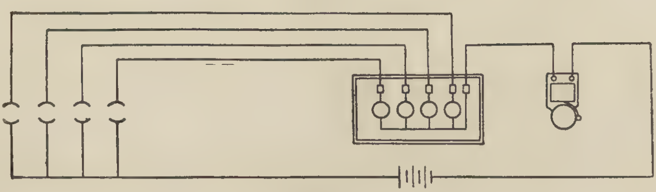


Fig. 396.

than earth-plates. In Fig. 394 four pushes are shown in connection with the same bell, the push branches being jointed to the main wires of the circuit. Fig. 395 shows a method by which two bells in separate rooms may be rung from one push by means of a two-way switch. By using a multiple-way switch, any required number of separate bells can be rung from one point. A simple indicator circuit is represented in Fig. 396. Additional pushes can be fitted in any room of a house by connecting them in parallel with the pushes already fixed.

Fig. 397 shows the wiring for a continuously ringing bell.

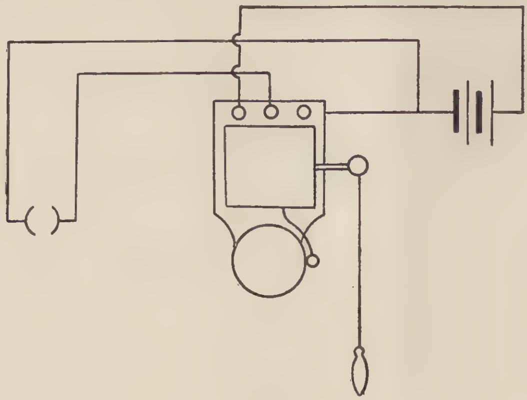


Fig. 397.

An ordinary burglar alarm circuit is shown in Fig. 398. When contact is made a lever on the bell is dropped, placing the bell in communication with the battery through the third terminal, and the bell continues to ring until put out of action. The circuit can be cut off during the day by means of the two-way switch.

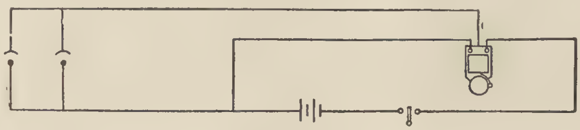


Fig. 398.

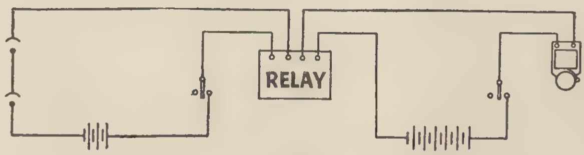


Fig. 399.

A more efficacious arrangement is that in Fig. 399, where provision is made for insuring the ringing of the bell even if the wires should be intentionally cut by burglars. In this circuit, the cutting of any wire immediately gives an alarm. Current is always flowing through the *relay*, the armature of which is thereby kept away from the contact stud. Directly an alarm is given, the circuit is broken and contact is made in the relay, thus starting the bell. For this circuit, Type S

Edison-Lalande cells are required on the alarm side, and the relay should have a resistance of not less than 200 ohms.

Fire alarms and other signals are wired similarly to electric bells, the details being settled to suit individual requirements.

TELEPHONES.

Under this head we only deal with types of instruments more particularly adapted for private installations in dwelling-houses, and in buildings of moderate size. Outline sketches of some patterns of domestic telephones are given below, together with simple diagrams indicating the necessary connections.

Direct Working System.—Instruments without induction coils, called "*domestic,*" or *direct working* telephones, will be found of great service for domestic use, as they can be applied to electric-bell circuits with very little trouble and expense.

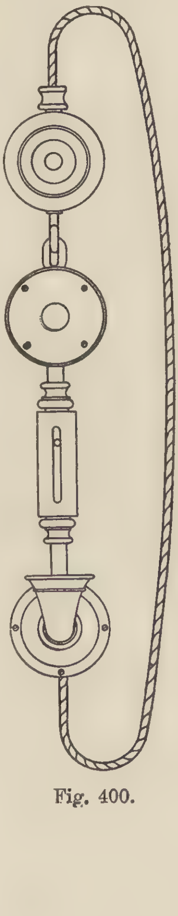


Fig. 400.

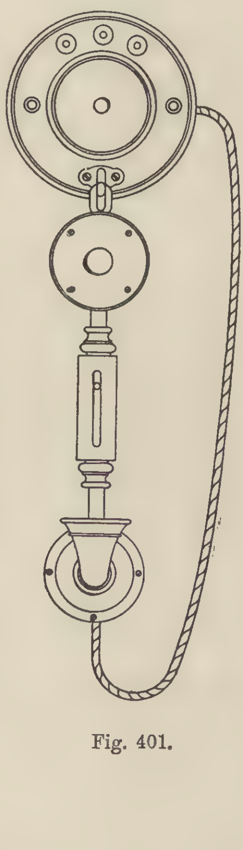


Fig. 401.

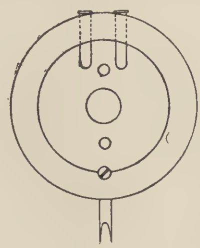


Fig. 402.

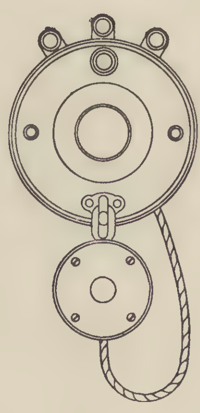


Fig. 403.

No alteration need be made to existing bells, wires, and batteries if these are in good condition. Telephones of this type can be used for distances not exceeding 200 yards. Fig. 400 shows a hand combination-telephone with push suitable for rooms or offices. Fig. 401 illustrates a similar instrument fitted to a three-terminal wall-box with bell and automatic switch.

Fig. 402 is a wood block with hook prepared to take a telephone as illustrated in Fig. 400. An ordinary bell-push can be fitted to this block. Fig. 403 shows a wall-pattern telephone with three-terminal wall-box, automatic hook, and bell-key.

Fig. 404 contains front and back views of a through-connection plug board designed for cutting out the bell and indicator of any line in a bell and telephone system, leaving the indicator and bell in circuit with other lines.

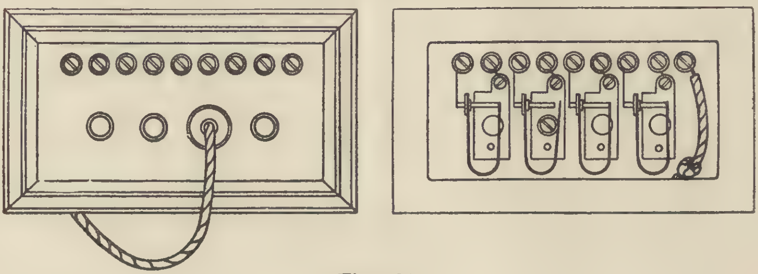


Fig. 404.

Fig. 405 is a diagram of the connections for placing four rooms in communication with a "central station" through an ordinary indicator. This diagram shows the manner in which the system can be engrafted upon an existing electric-bell installation. In this case the rooms cannot be called up from the central station.

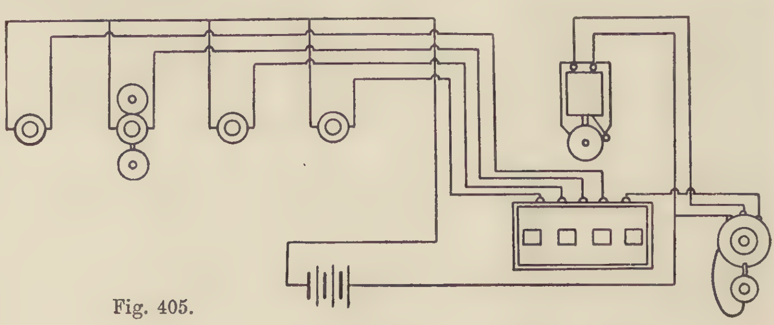


Fig. 405.

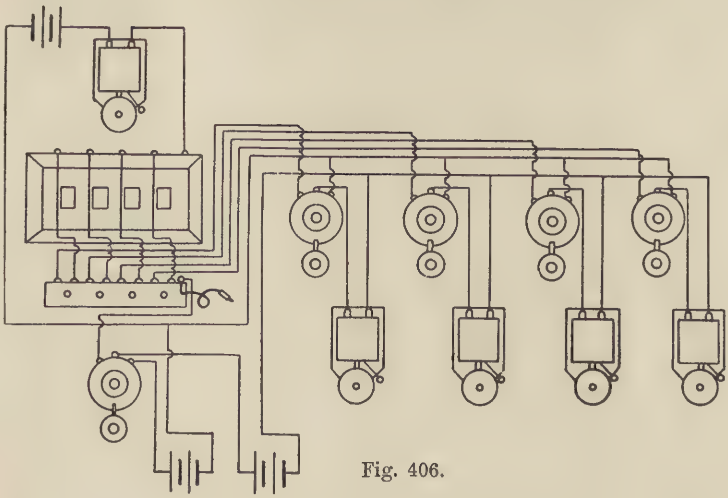


Fig. 406.

Fig. 406 is a diagram showing the application of telephones and a through-connection plug board (as Fig. 404) to a bell installation, so that the central station can be rung up from each instrument and *vice versa.*

Fig. 407 is a diagram of the connections for two telephones communicating in either direction, a battery being fixed at each instrument. If only one battery be used, a third wire must be run as in Fig. 408.

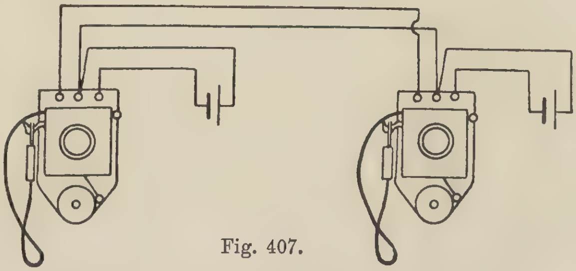


Fig. 407.

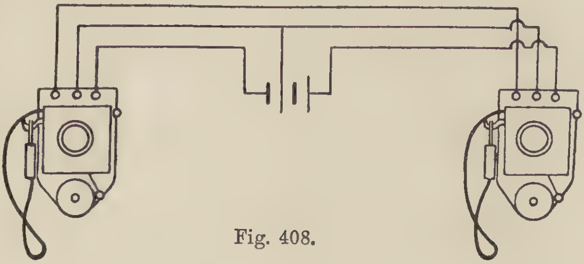


Fig. 408.

Reply and Call System.—This system permits calls to be made from a central station to any number of sub-stations, and from any sub-station to the central station, without the necessity for an indicator or annunciator switchboard. Further, by the addition of plugs at the central instrument, any two stations can be placed in direct communication.

Fig. 409 is a front view of a "Hunningscone-Deckert" central station instrument, with microphone and induction coil, for the "reply and call" system. Below the transmitter is a *line selector* for putting any instrument in circuit, and at the top of the instrument is a series of plug holes for intercommunication between sub-stations.

Fig. 410 shows a Hunningscone-Deckert sub-station instru-

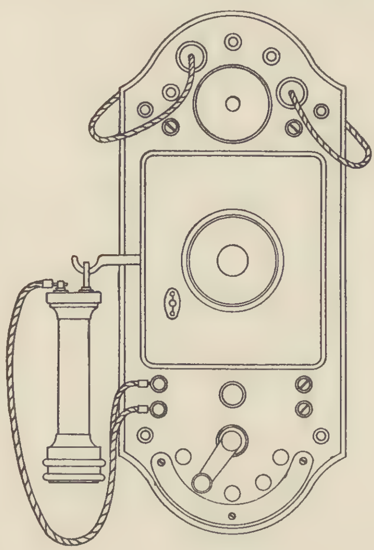


Fig. 409.

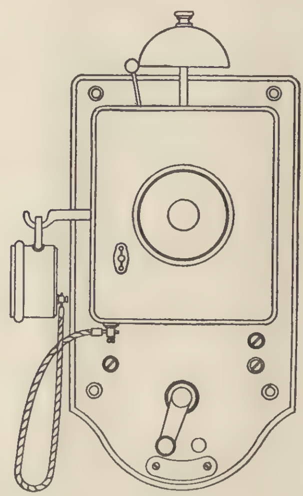


Fig. 410.

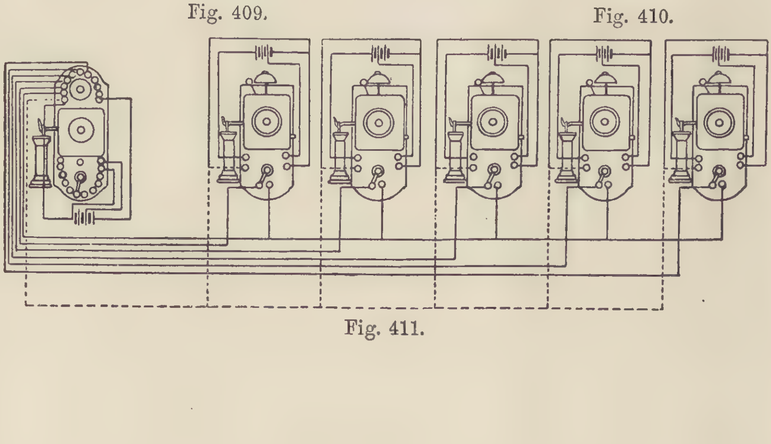


Fig. 411.

ment, with microphone, induction coil, and switch, for "reply" and "call."

Fig. 411 is a diagram of the connections for a system of five sub-stations, any of which can be rung up from, or can ring up, the central station, and any sub-station can be placed in direct communication with any other sub-station by the plug board on the central instrument.

The Berliner type of central station telephone is shown in Fig. 412. Here the different lines are selected by a series of separate switches in the upper part of the instrument, and the intercommunication plug board is at the bottom. The advantage of this arrangement is that several lines can be called up and spoken to simultaneously from the central station. The sub-

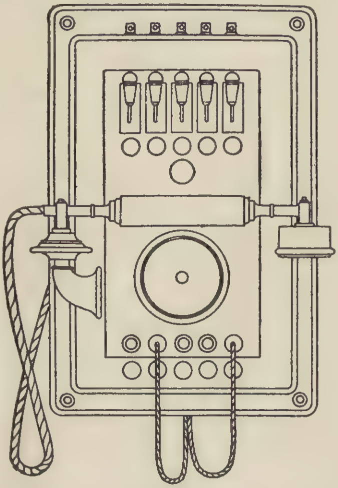


Fig. 412.

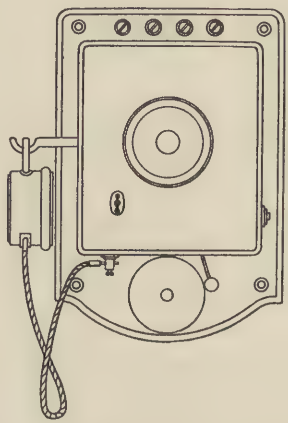


Fig. 413.

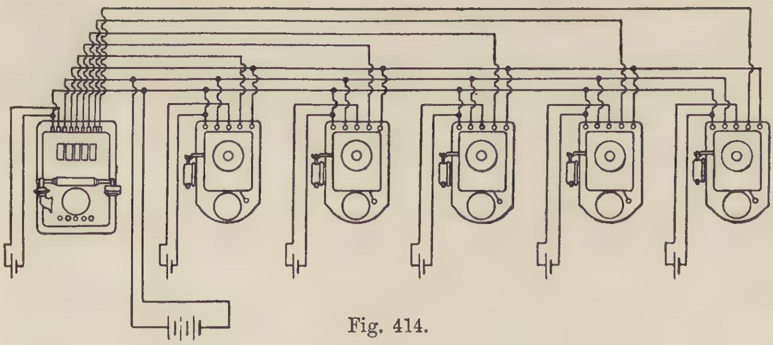


Fig. 414.

station telephone is illustrated in Fig. 413. The chief feature of this is an automatic device for changing over the call line so that it is unnecessary to have a separate switch for the purpose.

Fig. 414 is a diagram of the connections for a system of five sub-stations in communication with the central station, and through the plug board with each other.

LIGHTNING CONDUCTORS.

Conductors and Fittings.—Although galvanised iron is sometimes used, the best material for lightning conductors is copper, and in most cases it will in the end prove to be the cheapest.

Copper tape and copper rope are largely employed. Tape possesses several advantages. It can be obtained in lengths which largely obviate jointing, it can be easily and securely jointed, and it is easy to fix owing to its flexibility. Ropes are satisfactory if strands of adequate diameter be employed, but they are more conspicuous than tape, they expose greater surface to the action of the elements, and present interstices for the lodgment of dirt, soot, and water.

The utmost importance attaches to the joints of the conductors. Ordinary soldering renders joints perfect for a time, but will not stand the strains due to continual expansion and contraction. Therefore the use of well-designed joint-boxes is always desirable. Joint-boxes of various patterns can be obtained for tee, two-way, four-way, or ordinary joints, and are furnished with lugs, screws, or straps for fixing in any position or part of a building. Joints are made in such boxes by pouring solder over the spliced and tinned conductors laid in the box.

Conductors must always be attached to the building by metal holdfasts, permitting expansion and contraction due to temperature changes. They should be taken down the side most exposed to rain, and connected to internal and external water pipes and gas pipes of all kinds. Conductors must never be bent abruptly round sharp corners, but they may be taken through projecting masonry if holes of ample size are provided. Where iron conductors are used they must always be painted, whether galvanised or not.

Terminals.—Some forms of ordinary air terminals are illustrated in Fig. 415.

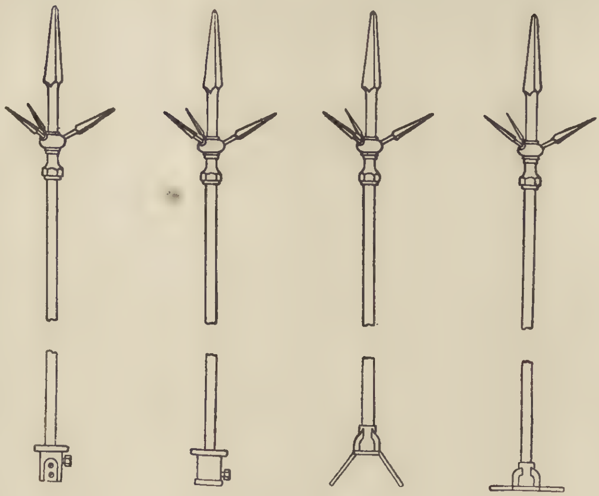


Fig. 415.

A type of air terminal recommended by Mr. Killingworth Hedges, M.Inst.C.E., is shown in Fig. 416. A gun-metal circular box furnished with pockets to receive the points is pinned to the central rod, and is fixed, together with the points, by pouring solder into the inside cavity. Fig. 417 shows a variation of the same type for cable, the strands of which are mechanically and electrically connected to the points in a similar box.

Fig. 416.

Fig. 417.

Space Protected.—Theoretical calculation of the space protected by a lightning conductor is not entirely reliable, but satisfactory results may generally be insured by adopting the rule that *a lightning conductor protects a conical space of which the apex is at the terminal of the conductor, and the radius is equal to the height of the terminal from the ground.*

From this rule it is clear that unless the terminal is sufficiently high, the whole of a building cannot be efficiently protected by a single conductor. In most cases it would be impracticable to make the height adequate for the fulfilment of such a purpose,

and, further, one tall terminal is far less efficient than several points at regular intervals along a roof.

During a thunderstorm, not only the atmosphere but also the ground is charged with electricity, and the greater the number of points, the greater is the likelihood that pressure will be equalised between the clouds and the earth. Hence the practice is to employ a number of terminals united by horizontal lines of copper cable, or tape, and connected to earth by one or more conductors, the number of which varies with the size of the building.

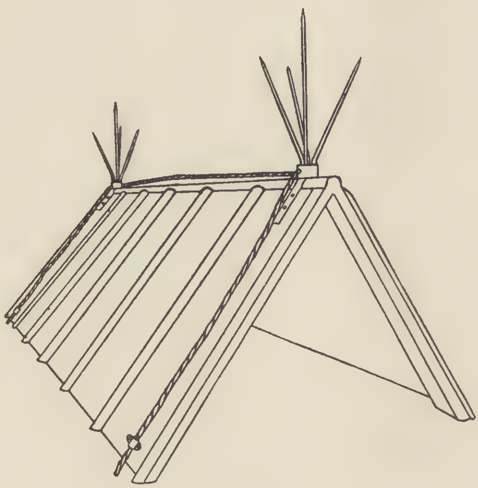


Fig. 418.

Fig. 418 illustrates the application of the Hedges system to part of the roof of Westminster Abbey, the terminal points being connected by cables to a horizontal conductor running along the ridge of the roof. Fig. 419 shows an octagonal coronal suitable for a chimney, the frame being of copper tape and joined to a tape earth-conductor. The four points can be arranged to screw into the cap of the shaft, so as to fix the coronal. Similar coronals are made in other forms suitable for chimneys, roofs, and other details of buildings.

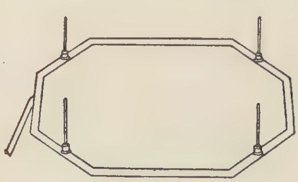


Fig. 419.

Earth Connection.—The lower extremity of the conductor or conductors must be buried in permanently damp soil. Therefore

proximity to rain-water pipes and drains is desirable. Earth connection may be made in various ways, some of which are described below.

Fig. 420 represents a simple connection recommended by Dr. Mann, in which the opened strands of a rope are buried in a bed of coke.

Fig. 421 illustrates the Hedges system of earth connection, in which the *tubular earth* consists of a specially constructed pipe, $1\frac{1}{4}$ in. or 2 in. diameter, perforated at the lower end and provided with a steel spike. This end-piece is driven into the ground, and other lengths are screwed on until the desired depth is

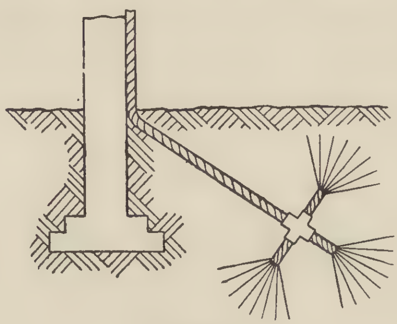


Fig. 420.

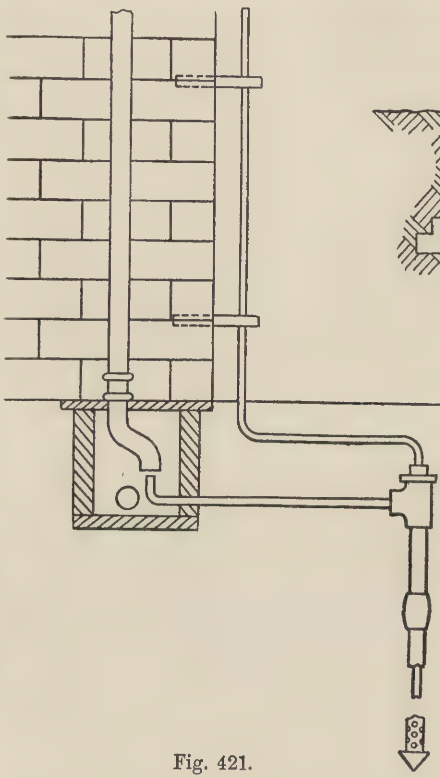


Fig. 421.

attained. The conductor is dropped down the tube, and electrical connection is made by a brass cap and soldering. A branch pipe can be led to the nearest water-pipe, so that water may run through the tubular earth fitting, thus insuring the necessary

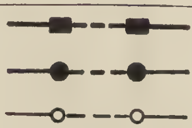
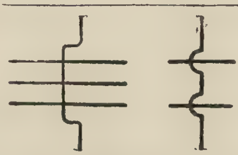
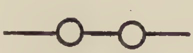
moisture. This form of earth connection takes up little room and is very easily applied.

Copper and galvanised earth plates are frequently used, being buried in permanently wet earth and surrounded by cinders or coke. The usual dimensions for an earth plate are 3 ft. by 3 ft. by $\frac{1}{16}$ in. thick. Great care must be taken to make a secure connection between the conductor and the plate. It is often difficult to bury the plate to the depth necessary for reaching moist earth, and the connection of the plate with the conductor is generally impaired after being buried for a few years.

No part of a lightning-conductor system is more important than the earth connection. Being buried, it is generally forgotten, and if the connection should become impaired, the whole system will be worse than useless, giving rise to a feeling of security where none exists.

KEY DIAGRAM

In the drawings and diagrams illustrating this chapter various conventional signs and methods of expression are adopted, some of which, for the convenience of readers, are explained below.

N and S	on the diagrams of dynamos indicate the *north* and *south* poles of the field magnets.
+ and −	against conductors, or the terminals of electrical apparatus, indicate *positive* and *negative* respectively.
O	against a conductor indicates that the conductor is *neutral* or at *earth potential.*
	represents a dynamo, the circle being the *commutator*, and each tangent the *brush*, at the end of which the *terminal* is shown by a circle.
	represents either a primary or a secondary battery, each cell including one positive and one negative element, the first indicated by the thin line and the latter by the thick line. The number of cells intended in any diagram can be found by counting the thin or thick lines.
	Fuses are thus represented in the diagrams, approximately according to their weight and capacity.
	represent main switches.
	indicate that conductors cross without electrical or mechanical contact or connection.
	Lamps connected *in parallel* between two conductors.
	Lamps connected *in series* on one conductor.
	Diagrammatic representation of electric bell push.
	Diagrammatic representation of burglar alarm contact.

Chapter XIII.

MATERIALS.

THIS chapter contains only so much as is necessary to form an elementary introduction to the consideration of the subject of the materials used in building construction. More complete information with respect to them will be found in Part III. of this work.

BRICKS.

Manufacture.—Ordinary building bricks are made of clay or other earths subjected to various processes, such as clearing from stones, grinding if necessary, and mixing in some cases with chalk. These vary somewhat according to local practice, influenced by the nature of the material. The clay is formed, after mixing with water to a plastic condition, to the required shape by hand in moulds, or by machines, dried, and then burnt either in *kilns* (large ovens) or *clamps* (piles of the dried bricks themselves).

Hand-made Bricks have a *frog*, or indentation, on one side, which lightens the brick and forms a key for the mortar.

Machine-made Bricks are generally denser and heavier than those made by hand. In some machines the bricks are cut off by a wire: they then have no frog; in others the clay is pressed when nearly dry in a mould, and these generally have a frog, and are often pierced through with holes to make them lighter.

Classification of Bricks.—This differs in various localities, but in some brickfields near London there are three general classes:—

Malms, in which the clay is mixed with about $\frac{1}{16}$ chalk, and cinders.

Washed, in which less chalk is added to the clay.

Common, in which no chalk is added.

These classes are divided into several varieties, the principal of which are—

Cutters or *Rubbers* of even texture and very soft, so that they can be cut and rubbed to accurate shapes and to a smooth face.

Facing Paviors, hard-burnt malm bricks of good shape and colour, used for facing superior work.

Hard Paviors are more burnt, slightly blemished, and used for copings, superior facing, etc.

Stocks, good hard bricks, used generally for ordinary good work.

Grizzles and *Place Bricks*, which are weak, under-burnt, inferior bricks.

Chuffs are bricks on which the rain has fallen when they were hot, making them full of cracks and useless.

Burrs are lumps of over-burnt bricks vitrified and run together.

MACHINE-MADE BRICKS may be classed as *Pressed* or *Wire-cut*, of each of which there are several varieties.

Characteristics of good ordinary Bricks.—They should be well burnt, hard, ringing well when struck together, free from cracks and lumps, especially lumps of lime, regular in shape and uniform in size, not absorbing more than $\frac{1}{6}$ of their weight of water.

Size and Weight.—This varies; but near London ordinary bricks are about $8\frac{3}{4}$ inches long, $4\frac{1}{4}$ inches broad, and $2\frac{1}{2}$ inches thick, and weigh about 7 lbs each.

In order to obtain good brick-work, the length of each brick should just exceed twice its breadth by the thickness of a mortar joint.

Varieties of Bricks.

Besides the ordinary bricks above described there are innumerable varieties in the market, the most important of which are:—

WHITE BRICKS, made from peculiar clays, sometimes with the addition of a large proportion of chalk. The best known are the *Suffolk* and *Beaulieu* bricks.

Gault Bricks are from the clay between the upper and lower greensand. They are white, and generally very dense and heavy, being to some extent lightened by a large frog, or by holes through their thickness.

STAFFORDSHIRE BLUE BRICKS are made from the local clays, which contain some 10 per cent of oxide of iron, converted under great heat into the black oxide. They are of a dark blue colour or nearly black. They have an enormous resistance to compression, are very hard, non-porous, very durable, and much used for paving, copings, etc.

FAREHAM RED BRICKS are made near Portsmouth, and are much used for superior face-work.

ENAMELLED BRICKS have a white china-like surface, and are used for lavatories, dairies, etc.

DUTCH CLINKERS are very small, well-burnt hard bricks, used for facing.

MOULDED and PURPOSE-MADE BRICKS may be obtained of every possible form, and not only save much labour in cutting ordinary bricks, but weather much better, being as a rule of better material.

Fire Bricks are made from "fire clays," found generally in the coal-measures. They are capable of withstanding very high temperatures, and are much used for lining furnaces, etc.

Terra Cotta is made from mixtures of peculiar clays with ground glass,

pottery, and sometimes sand. It is apt to warp in manufacture, but is much used for building, is very hard, strong, and durable in any atmosphere.

Pipes and Clay Goods.—These are innumerable in form, but it is important to distinguish between the material of which they are made.

Unglazed ware is made from ordinary clays, weak, and unable to resist frost.

Fire-clay Ware, made from fire clays and glazed, used for common work.

Stoneware, made from Lias clays, glazed, is very strong, durable, and used for the best work.

Terra Cotta, made from the material above described. It is inferior to stoneware, being more absorbent, but better than fire-clay goods.

STONE.

Characteristics of good Building Stone.—Stone is found of many different descriptions and qualities, but the chief characteristics required in a good stone for building are as follows :—

DURABILITY, which depends chiefly upon chemical composition; for a large proportion of lime will render the stone unfit to resist the acid atmosphere of towns—a stone that is not durable out of doors is said to "weather" badly. The durability is, however, to some extent influenced by its PHYSICAL STRUCTURE, thus marble is more durable than chalk, though chemically the same. HARDNESS (for quoins, etc.), FACILITY FOR WORKING (for carvings, etc.), and APPEARANCE, have sometimes to be considered.

Classification of Building Stones may be taken as follows :—

Granites and other igneous rocks.	Sandstones.
Slates.	Limestones.

Granite is composed of quartz, felspar, and mica. It is, as a rule, very durable and hard to work, and is used for heavy engineering structures and for massive buildings, also in the parts of ordinary buildings, such as steps, that undergo most wear.

Mica and some kinds of felspar are liable to decay, but quartz is always hard and durable; therefore the more quartz a granite contains the better.

The best-known granites are found in Scotland and Cornwall.

Slates for Roofing.—They should be fine grained, hard, with a metallic ring, not friable at the edges; tough, so as not to splinter when cut or holed; and non-absorptive. The best varieties come from Wales.

Slate is also used in slabs of from 1 to 3 inches thick for cisterns, sills, skirtings, landings, etc.

Sandstones are found in great variety. They consist of grains of sand held together by cementing material, upon the nature of which latter depends their durability.

The best-known sandstones are as follows :—

YORKSHIRE SANDSTONES.—These have a coarse grit, are very strong, can be obtained in large blocks of a light brownish-white colour, and are much used for heavy engineering work. The best-known quarries are *Bramley Fall*, *Bradford*, *Scotgate Ash*, etc. etc.

MANSFIELD STONE is found in Nottinghamshire in two colours, red and white, and is well adapted for ashlar work, columns, etc.

CRAIGLEITH STONE, found near Edinburgh, is the most durable sandstone in the country, and useful for any good masonry.

Limestones consist of grains of carbonate of lime cemented together by the same substance, or by the same mixed with silica.

They vary greatly in texture, being either *granular*, with grains varying much in size, or *compact*, not showing grains.

The principal varieties are :—

BATH STONE.—An even-grained, comparatively soft white stone ; some of it weathers badly. It is obtainable in large blocks, and much used for mouldings and carved work. There are several quarries, such as Box, Combe, Corsham, etc.

PORTLAND STONE.—Several distinct kinds are found in the quarries. *Roach and Whitbed Roach* are full of shell casts, and not much used in ordinary buildings. *Whitbed* and *Basebed*, known also as "*Bestbed*," are most valuable white building stones, of even texture, and durable in most positions. Both descriptions present the same appearance, but Whitbed is harder to work and more durable than the other.

KENTISH RAG is a hard, compact, non-absorbent gray stone, very difficult to work, and used chiefly for rubble. (See Part I.)

YELLOW MANSFIELD STONE is a magnesian limestone, composed almost entirely of carbonate of magnesia and lime, and is an even-grained stone fit for ashlar and carving.

CAEN STONE is found in Normandy, but much used in this country. It is of a cream colour, very soft when just quarried, easily worked and carved, but weathers badly.

Marble is a very dense, compact form of limestone that will take a polish ; some varieties are beautifully marked, and are used chiefly for decorative purposes.

Natural Bed.—The importance of placing stones in walls with their natural beds—in the layers in which they were geologically deposited horizontal—has been mentioned in Part I. ; also that in cornices or over hanging work the natural bed should be vertical.

LIMES AND CEMENTS, MORTAR, GROUT, CONCRETE, ETC.

LIME.

Quicklime is produced by burning limestone in a kiln, the carbonic acid is driven off, and the result is quicklime.

Slaking is effected by thoroughly wetting a quicklime and covering it up. It then swells, becomes hot, gives out puffs of steam and falls to powder, which is called *slaked lime.*

The slaking process is very violent with rich limes, less so with poor limes, and very slight in the case of hydraulic limes.

Setting.—When a lime or cement is made with water into a pat, and exposed to the air, it will harden less or more according to its quality, until in most cases it becomes quite hard throughout its bulk. With hydraulic limes and cements the hardening will take place even better if the pat is placed under water.

Pure, Rich, or Fat Lime is that produced from pure limestones, such as marble or chalk, containing nothing but carbonate of lime. Such a lime slakes furiously, but a pat made from it will never thoroughly set or harden, even in the air, and if placed under water it will simply dissolve away. Rich limes cannot, therefore, make good mortar or concrete, but are the best for whitewashing and sanitary purposes.

Poor Lime is from limestone containing useless impurities, and it shares all the defects of rich limes.

Hydraulic Limes are produced from limestones which contain from 5 to 30 per cent of clay in a peculiar form. They slake with more or less difficulty, but will set, becoming quite hard in air or under water, and are therefore adapted for making good mortar and concrete.

Test.—To ascertain whether a limestone is hydraulic, it should be made red hot, to drive off the carbonic acid. The resulting quicklime should be slaked, made up with water into a pat, and then placed under still-water, to see if it will set there. If it does not set, but dissolves or becomes disintegrated, it will show that the lime is not hydraulic.

CEMENTS.

Cements are either natural or artificial.

Roman Cement is the best-known natural cement in this country. It is made by burning nodules containing some 30 to 45 per cent of clay, found in the London clay. This cement is of a rich brown colour, and weighs about 75 lbs. a bushel. It sets in about 15 minutes, and is valuable for tide-work, or stucco, but its ultimate strength is very small.

Other quick-setting Cements.—For the names and uses of other somewhat similar cements, see p. 199. They are not used for mortar or concrete, but chiefly for plasterers' work.

Portland Cement is an artificial compound made by mixing chalk and clay in water in the proportion of about 75 per cent chalk to 25 per cent clay, drying and burning the mixture in kilns, and grinding the resulting "clinker" to such a fineness that 90 per cent of it will generally pass a sieve of 2500 meshes to the square inch, and it will weigh about 115 lbs. per bushel.

The result is a fine powder of greenish gray colour, which when mixed into a pat will set either in the air or under water, becoming hard in twenty-four hours, attaining considerable tensile strength in seven days, and in course of time a strength far greater than that of any other cement.

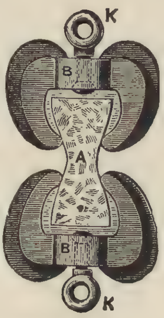


Fig. 422.

TESTING.—The tensile strength of samples of Portland cement is ascertained by forming the cement into *briquettes* or blocks, of the form shown in Fig. 422, the section at A being generally $1\frac{1}{2}$ inch square. These are broken in a machine which applies slow tension upwards and downwards at K and K.

A good cement after setting seven days under water is expected not to break under a less weight than of about 800 lbs. on the area A ($2\frac{1}{4}$ square inches), *i.e.* 355 lbs. per square inch.

COOLING.—It is of the utmost importance that Portland cement should be thoroughly *cool* when used—all the lime in it thoroughly air-slaked—otherwise it may swell in the work when used, and cause much damage. In order to cool it, it should be spread out on a floor protected from the weather, and turned over daily for some weeks, so that every part of it may become thoroughly air-slaked.

MORTAR—CONCRETE.

Mortar is made by mixing to the consistency of soft porridge limes or cements with clean sands, the proportion of which depends upon the description of the lime or cement.

PROPORTION OF SAND.—*Rich and Poor Limes* may be mixed with a large proportion of sand (3 or 4 measures of sand to 1 of lime), for in any case they make mortars with very little strength. *Hydraulic Limes* make a good mortar with 2 of sand to 1 of lime. *Roman Cement Mortar* should not have more than 1 or $1\frac{1}{2}$ sand to 1 cement, and is then a very weak mortar. *Portland Cement* will make a very strong mortar when mixed with 2 or 3 of sand, and even with 5 of sand—a mortar better than any of those made from lime.

Grout is a weak mortar made liquid by the addition of water, and used to pour into joints and interstices which cannot be got at with the stiffer material.

Concrete is a conglomerate or thorough mixture of shingle, broken stones, or similar material, with lime or cement, sand and water, which form a mortar filling the interstices between the pieces of stone. The proportions of ingredients mixed determine the quality of this mortar, which in its turn governs the strength of the concrete.

Proportions of Ingredients.—Concrete is generally described with reference to the bulk (when dry) of the materials comprising it. Thus for an important work the concrete might be 1 Portland cement, 2 sand, and 5 of shingle or broken stone; for less important work 1 Portland cement, 3 sand, and 8 shingle.

Laying Concrete.—This should be carefully done in horizontal layers, about 12 inches thick, well rammed, the surfaces being kept clean, and the material not disturbed when setting.

PLASTER AND ASPHALTE.

Plaster for common work is a sort of mortar spread over surfaces to make them smooth. It is laid on in successive coats, the composition of which varies, and is given at pp. 199-200.

Plaster of Paris, or calcined gypsum, is a very quick-setting material, the basis of several cements, for which see p. 199.

Asphaltes are combinations of bituminous and calcareous matter. The best are natural—found chiefly in Switzerland—but there are many artificial imitations made with pitch and chalk.

The material is generally heated, and poured in a molten state over the surface to be covered. Some kinds are laid as powder and compressed by ramming.

The best varieties of asphalte are from Seyssel, and Val de Travers in Switzerland.

TIMBER.

Appearance of Cross Section.—The timber used in engineering and building works is obtained from a class of trees which grows by the deposit of successive layers of wood outside under

the bark, while at the same time the bark becomes thicker by the deposit of layers on its under side.

Annual Rings.—The cross section of such trees (see Fig. 423) consists of several concentric rings or layers, each ring consisting in general of two parts—the outer part being usually darker in colour, denser and more solid than the inner part. The difference between the parts varies in different kinds of trees.

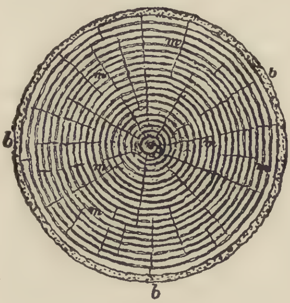


Fig. 423.

These layers are called *annual rings,* because one of them is, as a rule, deposited ever year. Sometimes, however, a recurrence of exceptionally warm or moist weather will produce a second ring in the same year.

Medullary Rays and Silver Grain.—In the centre of the tree is a column of pith p from which planes, seen in section as thin lines m m, radiate toward the bark b, and in some cases similar lines m m converge from the bark toward the centre but do not reach the pith.

These radiating lines are known as "medullary rays" or "transverse septa." In many woods they are not discernible by the eye, but when they are of large size and strongly marked, as they are in some kinds of oak, they present, if cut obliquely, a beautiful figured appearance, known as "silver grain" or "felt."

Heartwood and Sapwood.—As the tree increases in age the inner layers are filled up and hardened, becoming what is called "heartwood," the remainder being called "sapwood." The latter is softer and lighter than heartwood and can generally be easily distinguished from it.

This is important, as the heartwood is in most trees far superior to the sapwood in strength and durability, and should alone be used in good work.

Characteristics of good Timber.—Good timber should be from the heart of a sound tree—the sap entirely removed. The wood, uniform in colour and substance, straight in fibre, free from large or dead knots, flaws, shakes, or blemishes of any kind.

The annual rings should be regular in form; close and narrow rings indicate strength, porous and open rings are signs of weakness. Good timber is sonorous when struck. A dull heavy sound betokens decay.

Classification of Timber.—For practical purposes timber may be classed as :—

SOFT WOOD, including fir, pine, spruce, larch, and all cone-bearing trees.

HARD WOOD, including oak, beech, ash, elm, mahogany, teak, etc.

Market Forms of Timber.—The following are the most common forms in which timber is sold :—

Logs, being trunks of trees with the branches lopped off.

Balks or *square timber*, being the trunks roughly squared, generally by the axe, sometimes by the saw.

Planks, being parallel-sided pieces 2 to 6 inches thick, 11 inches wide, and from 8 to 21 feet long.

Deals. Similar pieces 9 inches wide, and not more than 4 inches thick.

Battens, being like deals, but only 7 inches wide.

DESCRIPTIONS OF DIFFERENT KINDS OF TIMBER.

SOFT WOODS.

Red or Yellow Fir, or *Northern Pine*,[1] is obtained chiefly from the Baltic or Russia.

Its cross section shows distinct annual rings, the hard portions of which are much darker than the others ; the wood is resinous, and there are no medullary rays visible.

The best timber of this description comes from *Memel*, *Dantzic*, and *Riga*, the balks being from 18 to 45 feet long and 12 to 16 inches square.

Yellow Deals come from the same ports, the best from *St. Petersburg*, *Archangel* ; and others from *Christiania*, and from *Gefle* and other Swedish ports.

All these are used for carpenters' work, and the best of the deals for joinery.

American Pine.—*Red Pine*,[2] so called from the colour of its bark, very like Memel timber, and *Yellow Pine*,[3] of a brownish-yellow colour when seasoned, are imported from Canada.

AMERICAN YELLOW PINE is of a very soft and even grain, and can be easily recognised by short, detached, dark, thin hair-streaks running in the direction of the grain, which show upon a planed surface.

It is invaluable for joinery, but is not so strong or durable for carpenters' work as Baltic timber.

Pitch Pine[4] also comes from North America. It has very strongly-marked annual rings, is full of resin when it has not been "bled," hard to work and to wear, very durable except in a moist atmosphere.

It is much used for heavy engineering structures, also for ornamental joinery and for parts, such as heads of steps, sills, etc., subjected to much wear.

Spruce,[5] or *White Fir*, comes both from the north of Europe and from North America.

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[1] Obtained from the *Pinus sylvestris* or *Scotch Fir.*

[2] Known also as *Canada Red Pine*, *Pinus rubra*, or *Pinus resinosa.*

[3] *Pinus strobus.* [4] *Pinus rigida.* [5] *Abies excelsa.*

The wood is of a yellowish white, with clear annual rings and hard glossy knots, by which it is easily recognised.

It shrinks and warps very much, and is fit only for common joinery and floors, packing-cases, and other common work.

Larch is found in various parts of Europe, the best being in Russia.

It is of a brownish-yellow colour, the hard parts of the rings being reddish. The wood is tough and durable, but shrinks and warps, and is used chiefly for posts and palings.

HARD WOODS.

Oak is found both in this country and also in America, Holland, and the Baltic.

British Oak is found in three principal varieties[1] which need not be described in detail.

It is in section of a light brown colour, with a hard surface, narrow and regular annual rings, and clearly-marked medullary rays.

The timber is very strong, hard, tough, and durable; is used for all purposes where strength and durability are required in engineering structures, and in buildings for sills, treads, superior joinery, keys, wedges, etc.

American Oak[2] has a straighter and coarser grain than English oak, but is not so strong or durable.

Dantzic, Riga, and Italian Oaks are chiefly used for ship-building. French Oak is very like British oak.

Wainscot is a form of oak that comes chiefly from Holland and Riga, is easily worked, and is so converted as to show the *silver grain.*

Beech is of a whitish-brown colour, with very distinct medullary rays and perceptible annual rings. The wood is hard, compact, and smooth, not difficult to work, very durable if always dry or always submerged, but decays quickly under alternate wet and dry or in damp places. It is used chiefly for piles, wedges, and carpenters' tools.

Ash is of a brownish-white, with yellow streaks, each annual layer separated from the next by a ring of pores. The sapwood is not generally distinguishable. The timber is tough, flexible, and durable when dry. It is too flexible for building purposes, and is used chiefly for tool handles and felloes and spokes of wheels.

Elm is found in several varieties. The heartwood is reddish-brown and the sapwood yellowish. No medullary rays visible. The wood is very fibrous, dense and tough, durable—the sapwood as well as the heartwood, except when alternately wet and dry. It is very useful for work under water, such as piles, and for various carpenters' purposes.

Mahogany is imported chiefly of two descriptions, *Honduras* or *Bay Mahogany* and *Spanish Mahogany*, the latter from Cuba.

The wood is of a golden-brown colour, often very veined and mottled, capable of receiving a good polish, and durable when dry and not exposed to weather. The *Spanish* is distinguished from the *Honduras* by a chalk-like substance in its pores. Both descriptions are used for handrails and furniture.

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[1] Stalk-fruited or Old English Oak, *Quercus robur* or *Quercus pedunculata.* Cluster-fruited or Bay oak, *Quercus sessiliflora.* Durmast oak, *Quercus pubescens.*

[2] White oak (*Quercus alba*) or *pasture oak.* Other kinds are also imported.

Teak or *Indian Oak* comes chiefly from Burmah. It somewhat resembles English oak, but has no visible medullary rays. It is stronger and stiffer, but splinters easily. It contains an aromatic resinous oil, which makes it very durable.

This timber is too expensive for general use in buildings, but is sometimes employed for treads of steps, floors, etc.

Greenheart comes from South America. Its section is full of pores like that of a cane, of a dark green colour, the sapwood not distinguishable from the heart, and the annual rings not perceptible.

It is the strongest timber in use, and contains an essential oil which preserves it for a time from the attacks of worms. These qualities make it very valuable for marine work, in which it is much used.

Seasoning.—Timber is best seasoned, and the sap dried up, by being stacked under cover with the air circulating freely round it. There are methods of seasoning by hot air, also by boiling and steaming, and other special processes, which cannot here be described.

Decay.—When timber is in positions where it is alternately wet and dry, or not well ventilated, it soon decays, the sapwood being generally the first affected.

Dry Rot takes place in confined positions. A fungus eats into the timber, makes it change colour, smell disagreeably, become brittle, and eventually reduces the fibres to powder.

Wet Rot occurs in the growing tree, and in positions where the gases generated can escape.

Preservation.—The best method of preserving timber from decay is to have it thoroughly seasoned and placed in well-ventilated positions.

Painting or *Charring* preserve timber if it is thoroughly seasoned ; if not, they do harm by confining the moisture and causing rot.

Creosoting consists in forcing creosote (oil of tar)[1] into the pores of the timber, by which the albumen of the wood is coagulated, worms repelled, and rot prevented.

There are many other methods of preserving timber, which are described in Part III.

Felling Timber.—The best season for felling timber is at midsummer or midwinter in temperate, or during the dry season in tropical climates, when the sap is at rest.

The age at which a tree should be felled varies with circumstances. The heartwood must be fully formed, but the tree must not have passed its maturity, which will be shown by the presence of young shoots and vigorous top-branches.

IRON AND STEEL.

Iron is produced by smelting different ores with a flux, which

[1] See Part III. p. 392.

extracts from them most of their impurities. The liquid iron runs out of the blast furnace into rough bars called "*pigs.*"

Hot Blast Iron is that produced by furnaces into which the air is admitted at a high temperature. When the air is not thus heated the resulting metal is known as *Cold Blast Iron.* There are but few cold blast furnaces now in the country.

PIG IRON.

Carbon in Pig Iron.—The bars or pigs run from the blast furnace are not pure iron, but contain several impurities, such as carbon, silicon, sulphur, phosphorus, and manganese.

Of these carbon is the most important. It is sometimes free, being visible as black specks, sometimes chemically combined when it is not visible.

EFFECT OF CARBON.—The effect of the *uncombined or free carbon* is to give a fractured surface of the iron gray colour, and to render it easily fusible.

The *combined carbon* does not show in the fractured surface, which is white and bright, the iron being very hard, brittle, and forms when fused a pasty mass, which will not freely fill a mould.

DIFFERENCE OF CARBON IN IRON AND STEEL.—It is important to remember that the materials produced from pig iron differ considerably as to the amount of carbon they contain, upon which depend many of their characteristics.

These materials are:—

Cast iron, containing from 2·0 to 6·0 per cent of carbon—a comparatively large percentage.

Steel, containing about ·10 to 1·5 per cent—a small percentage.

Wrought iron, containing, if perfectly pure, no carbon, but practically containing a trace.

Classification of Pig Iron.

Bessemer Pig, a distinct variety, free from impurities, but containing a little manganese and silicon ; made for the Bessemer process (see p. 355).

Foundry Pig, having a fracture of a gray colour, and useful to the iron founder.

Forge Pig, being almost devoid of free carbon, not fit for superior castings, but only for conversion into wrought iron.

Besides the above varieties, the pig iron of commerce is divided into six or eight classes.

CAST IRON.

Cast iron is obtained by remelting pig iron with a little limestone flux to get rid of its impurities, and running it into moulds.

Classification.—Gray Cast Iron is made from foundry pigs. No. 1, the darkest in colour, contains a large proportion of free carbon; is soft, very fluid when melted, and useful for very delicate castings. No. 2 is lighter in colour, less fluid, but is harder than No. 1 when cold, and good for casting girders, etc. No. 3 is of a still lighter colour, harder, more brittle, and adapted for heavy castings.

White Cast Iron is made from forge pigs; is very bright, hard, and unfit for castings, except the commonest, such as sash weights.

Mottled Cast Iron contains both gray and white, which can easily be distinguished on a fresh fractured surface.

The Structure of Cast Iron is highly crystalline; a bar broken across shows no sign of fibre—nothing but crystals close together.

Castings are made by running molten cast iron into sand, in which an impression of the article to be cast has been formed by means of a wooden pattern.

The shape given to castings is important. There should be no sudden changes of thickness, or sharp angles as in Fig. 424, but the thickness should change gradually and the angles be rounded off as in Fig. 425.

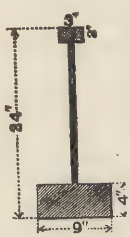


Fig. 424.

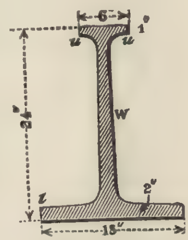


Fig. 425.

If these precautions are not attended to the casting will crack at the angles, or at any rate have a tendency to do so.

All castings should be smooth in surface, free from air bubbles or flaws, with perfect edges.

Chilled Iron is a very hard substance like white cast iron; it is produced on parts of castings which are required to be especially hard by placing pieces of cold iron against those parts when the metal is being run in.

Thus the running surface of a cast iron wheel may be chilled and made hard, the rest of the wheel being of a tough gray cast iron.

Malleable Cast Iron is made by extracting some of the carbon from cast iron, thus making it more like wrought iron in composition, which produces its toughness.

This is done for small castings by imbedding them in oxide of iron and raising to a red heat.

Iron so heated is softened to a certain depth all over the surface, and can be hammered or bent to a certain extent.

WROUGHT IRON.

The use of wrought iron has been practically superseded by that of Mild Steel for roofing, girder-work, and general constructive purposes.

Manufacture of Wrought Iron.—Wrought iron is manufactured from forge pig by the following processes.

Refining, or exposure when fused to a strong current of air which removes part of the carbon.

Puddling, by which the molten metal is still further exposed to a blast of air and oxidising substances in a reverberatory furnace. The remainder of the carbon is thus removed, and clotty lumps or "*puddle balls*" of pure iron appear.

Shingling, or hammering of these puddle balls so as to squeeze out the cinder and form them into "*blooms*."

Rolling, or passing the blooms while red hot between grooved rollers which convert them into *puddled bars*.

The effect of rolling is to elongate the crystals of the pig iron into *fibres*, giving the iron great strength and toughness.

Bar Iron is classified as follows:—

Puddled Bars, as obtained by the processes just mentioned, have but little tensile strength, and are used only for manufacture into better descriptions.

Merchant Bar or *Common Iron* is made by piling up short lengths of puddle bars, raising them to welding heat, and re-rolling. This improves the fibre of the iron, which is, however, still very hard, brittle, and useful only for the commonest purposes.

Best Bar is produced by cutting up merchant bars, piling, reheating, and rolling. It is tougher and more easily worked than merchant bar, and is generally used for ordinary good work.

Best Best and *Best Best Best* iron bars are those that have been submitted to three and four repetitions of the processes of piling, welding, and rolling.

The Market Forms of Mild Steel or Wrought Iron are very various. Besides square, round, half-round, flat, and other sections of bars, the sections shown below are the most common, and Figs. 426 to 430 are useful in building up iron structures of all kinds. The name of each is given below it.

Angle Irons.
Figs. 426, 427.

T Irons.
Figs. 428, 429.

Channel Iron.
Fig. 430.

I Beam or Joist.

Fig. 431.

Double-headed Rail.

Fig. 432.

Flat-bottomed Rail.

Fig. 433.

Tram Rail.

Fig. 434.

Sash Bar.

Fig. 435.

Corrugated Sheet Iron is made by passing sheets through grooved rollers which force them into waves or corrugations that immensely increase their stiffness and make them useful for roofing and other purposes.

Galvanised Iron is iron covered with a coating of zinc which protects it from oxidation.

Tests for Wrought Iron.—For all structures of any degree of importance the tensile strength of the wrought iron used should be tested.

A good iron should not only be strong but ductile, in order that it may not snap suddenly but stretch slightly under the shocks to which it may be subjected.

Such iron when torn asunder by slow tension in a testing machine should not break off short as in Fig. 436,[1] but draw out

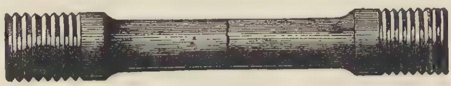


Fig. 436.

Fig. 437.

as in Fig. 437,[1] not only becoming longer, but also being reduced in sectional area at and near the point of rupture.

Tensile Strength and Elongation.—In order that both strength and ductility may be secured, engineers generally specify that iron bars for important work should bear a tensile stress of 23 or 24 tons per square inch, with an elongation of 15 to 20 per cent in 8 inches. Angle irons, T irons, and Plates have lower tests.

Rough and Forge Tests.—Iron may be further tested by being bent hot or cold to different angles, the limbs of T and angle irons being flattened down and rivets doubled cold without showing any signs of fracture. If they can stand such tests without cracking they are of good quality.

Fractured Surface.—"Whenever wrought iron breaks *suddenly* a crystalline appearance is the invariable result; when *gradually*, invariably a *fibrous* appearance."[1]

Small uniform crystals or fine, close, silky fibres indicate a good iron. Coarse crystals, flaws, blotches of colour, loose and open fibres, are signs of bad iron.

[1] From Kirkaldy's *Experiments on Iron and Steel.*

STEEL.

Steel varies very much in its characteristics according to the amount of carbon it contains.

Thus *Mild or Soft Steel* contains from ·10 to ·40 per cent of carbon. When more carbon is present it becomes *Hard Steel.*

CHARACTERISTICS.—Speaking generally, the following are the characteristics of steel, more especially as regards its harder varieties.

Hardening.—When raised to a red heat and suddenly cooled it becomes hard and brittle, thus differing from wrought iron, upon which this treatment has no effect.

Tempering.—After hardening as above, the steel may be softened again to any degree by reheating and again cooling; in this it differs from cast iron.

Other characteristics of steel are its sharp *metallic ring* when struck, its great *elasticity,* and its *retention of magnetism.*

Methods of making Steel.—Steel is generally made by one or the other of the following processes, in accordance with the class of steel required.

Blister Steel is produced by heating bars of the purest wrought iron with charcoal (carbon).

It has a crystalline structure, is covered with blisters and full of cavities, which render it unfit for edge tools, and it is used chiefly for conversion into better descriptions of steel.

Shear Steel is made by piling short lengths of blister steel and welding them together under the hammer, which closes the cavities, removes the blisters, and produces a more uniform material known as *Single Shear Steel.* A repetition of the piling and welding produces *Double Shear Steel.* Shear steel is used for large knives, plane irons, shears, etc.

Crucible Cast Steel is made by melting blister steel in crucibles, or by melting wrought iron with the addition of the necessary carbon in the form of charcoal. It is used for the best tools and cutlery.

Bessemer Steel is produced direct from pig iron which, when melted in a "converter," is deprived by a blast of air through it of all its carbon, the amount necessary to convert it into steel of the softness required is then added in the form of *spiegeleisen,* a variety of cast iron rich in carbon. The resulting metal is run out into ingots, which are hammered, rolled, and worked to the forms required.

Bessemer steel is much used for rails and for the tyres of wheels, also for large roofs and bridges, constructional work, etc.

The Basic Process is somewhat similar to Bessemer's, but that the converters are lined with material which deprives the pig iron of some of its impurities, thus enabling iron from the less pure ores to be converted.

The Open Hearth, otherwise known as the Siemens or Siemens-Martin Process, consists in melting pig iron or scrap in a regenerative furnace and then adding various substances, so that the molten metal may contain the

exact amount of carbon necessary to produce the description of steel required. Steel made by this process is much used for bridges, roofs, boiler-plates, constructional work, etc.

The Open-Hearth Process, like that of the Bessemer Converter, may be either "Acid" or "Basic." These terms have reference to the chemical composition of the material used for lining the hearths. At the present time the greater portion of the open-hearth steel manufactured in this country is from the "Acid"-lined hearth, requiring the use of an ore practically free from the impurities of phosphorus and sulphur.

Case-hardening is a process by which the surface of wrought iron is turned into steel. This is effected by red-heating the article to be case-hardened when immersed in bone dust, which adds carbon to the surface and turns it into steel to the depth of from $\frac{1}{16}$ to $\frac{3}{8}$ inch. The parts required to be hardened are then quenched. The process is useful for keys, and other articles where a hard surface is required to be combined with toughness.

Tests for Steel.—The remarks made at p. 354 with regard to the tests for wrought iron apply also to steel, except that in the case of steel the forge tests are much more important than for iron.

A recent specification for a large steel bridge requires that the bars and plates must have a tensile strength of not less than 28 tons or more than 31 tons per square inch, an elongation of not less than 20 per cent and a limit of elasticity of 15 tons. For further information on the tests and properties of mild steel for roofs, girders, and builder's steelwork, the student is referred to Part III., chap. iv.

Working Stresses for Iron and Steel.—The ultimate tensile stresses to which iron and steel are subjected when tested are the *breaking stresses.* When, however, they are used in structures it is so arranged that the members of iron and steel should be subjected only to safe *working stresses* such as certainly will not cause fracture.

Table of Breaking and Working Stresses for Materials for a Dead Load.

Material.	Breaking Stress in Tons per square inch.		Working Stress in Tons per square inch.	
	Tension.	Compression.	Tension.	Compression.
Cast Iron . . .	9	48	$1\frac{1}{2}$	8
Wrought Iron . .	23	18	5	4
Mild Steel . . .	26 to 32	...	$6\frac{1}{2}$ to 8	...
Timber, Fir . . .	$4\frac{1}{2}$	3	$\frac{1}{2}$	$\frac{1}{3}$
Oak . . .	$6\frac{1}{2}$	$4\frac{1}{2}$	$\frac{2}{3}$	$\frac{1}{2}$

Copper is found in the metallic state or is smelted from ores.

It is red in colour, not easily oxidised, very malleable, and has a greater tensile strength than any metal except wrought iron and steel.

It is used by the builder chiefly for slate nails, bell wires, and

lightning conductors, also for dowels, bolts, and fastenings in positions where iron would be corroded or rusted, and sometimes for covering roofs (see Part I.)

Lead is reduced from ores. It is an extremely soft and plastic metal—very malleable, fusible, heavy, and very wanting in tenacity and elasticity.

It is used for covering flat roofs, for flashings, pipes, bedding girders, etc.

SHEET LEAD is to be purchased in two forms—*cast* or *milled*; both are described according to their superficial weight. Thus 7 lb. lead means lead weighing 7 lbs. per square foot.

Cast Lead is thicker, heavier, and with a harder surface than milled lead, but subject to flaws and sand-holes, and of irregular thickness. It is cast in sheets from 16 to 18 feet long and 6 feet wide.

Milled Lead is rolled out thinner than the other, is more uniform in thickness, bends easily and makes neater work, but is not so durable as cast lead.

The *Weights of Sheet Lead generally used for Roofs* are as follows:—

	lbs. per square foot.	
Aprons and Flashings	5	Thicker if much exposed.
Roofs, Flats, Gutters	6 to 8	
Hips and Ridges	6 or 7	

LEAD PIPES of very large diameter may be made out of sheet lead, but smaller ones should be *drawn.*

Zinc is obtained from ores of the metal. It is easily fusible, malleable when pure, soon destroyed by air containing acid.

It is used by the builder for roof coverings, gutters, cisterns, chimney pots, slate nails, ornaments, and for covering iron (galvanising) to keep it from rusting.

Good sheet zinc is of uniform colour, tough, easily bent backwards and forwards without cracking. The gauges used for roofs are mentioned in Part I.

Tin is used for lining lead pipes and for small gas tubing. It is very soft, weak, and malleable, and more easily fusible than any other metal.

CHAPTER XIV.

STRESSES IN STRUCTURES.

THE subject of stresses in beams, simple or trussed, in braced structures such as roof principals or lattice girders, in columns or struts, and ties, together with the stability of walls and arches, is fully dealt with in Part IV., "Calculations for Building Structures." The present chapter deals in an elementary manner with a few of the simpler problems in the theory of construction.

Stress and Strain.—When a load or any force acts upon a structure or piece of material, it produces a change of form which is called the *strain.* The internal forces called out in the material to resist this strain are called the *stress.*

Thus a load hanging from a bar of iron lengthens it, causing a *strain*, and calls out in it the resistance of the fibres which are under a tensile *stress.*

These two terms are sometimes used indiscriminately, but it is more accurate to make the above distinction between them.

The Nature of the Stresses to which the different Parts of Simple Structures are subjected.

These stresses are as follows:—

Tension is the stress produced by pulling; it elongates the body upon which it acts, and tends to cause rupture by tearing it asunder.

Thus if a rope or a bar of iron is subjected to a sufficient pulling or tensile stress it will break or tear across.

Compression is the stress produced by pressure; it shortens the body to which it is applied and tends to cause rupture by crushing.

Thus a block of stone bearing a weight is under compression, and if the weight is sufficient it will be crushed.

Transverse Stress is one caused by bending the body on which it acts, and it tends to break it across.

Fig. 438.

Thus the weight in Fig. 438 bends the beam as shown, until, if the weight is sufficiently increased, the beam will break across as in Fig. 439.

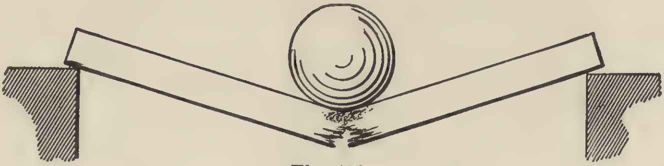


Fig. 439.

Shearing Stress is that produced when one part of a body is forcibly pressed or pulled so as to tend to make it slide over another part.

Thus when two plates riveted together as in Fig. 440 are separated

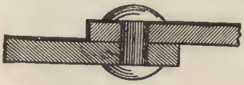


Fig. 440.

Fig. 441.

by pulling (or pushing) in opposite directions one plate slides upon the other and the rivet is sheared as in Fig. 441.

Bearing Stress is that which occurs when one body presses against another so as to tend to produce indentation or cutting.

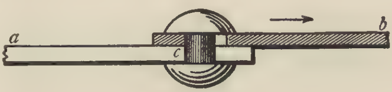


Fig. 442.

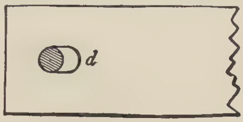


Fig. 443.

In Fig. 442 the plates *a* and *b* being pulled in opposite directions, the rivet *c* being of harder iron than the plate has borne upon it, making the hole larger, as shown at *d*, Fig. 443.

Load.—The load or weight upon a beam may be either concentrated at the centre as in Fig. 444, or uniformly distributed over the whole beam as in Fig. 445.

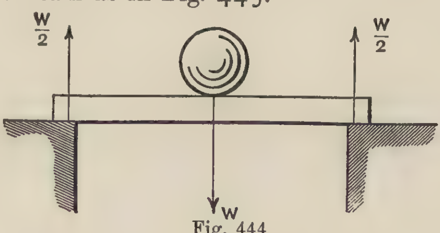


Fig. 444.

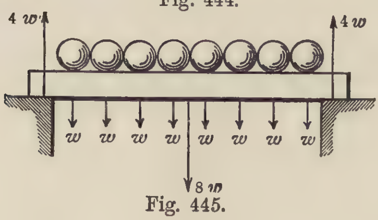


Fig. 445.

There may be concentrated loads at any point or points in the

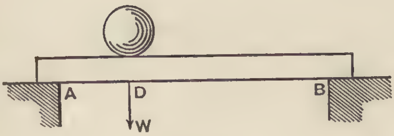


Fig. 446.

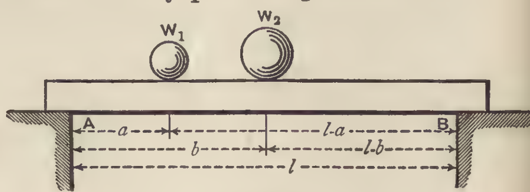


Fig. 447.

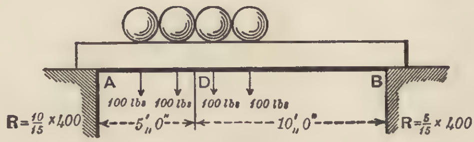


Fig. 448.

length of the beam, as in Figs. 446 and 447 ;[1] or the load may be uniformly distributed over a portion only of the beam, as in Fig. 448.

Weight of Beam.—In addition to the external loads represented in the figures by W and *w*, the weight of the beam or girder itself must, when it is large and heavy, be considered.

A Dead Load is one which is very gradually and steadily applied, and which remains steady.

Thus water poured gradually into a tank, supported by a girder, would be a dead load, and so would the tank and the weight of the girder itself.

A Live Load is one which is suddenly applied, as in the case of trains coming suddenly upon a bridge. It is generally taken as equivalent in effect to double its amount of dead load. Thus a live load of 10 tons would produce the same amount of stress as a dead load of 20 tons.

A Mixed Load, consisting partly of live load and partly of dead load, may be reduced to an equivalent amount of dead load by doubling the live load and adding it to the dead load.

Thus, if a structure weighs 500 tons (dead load), and is subject to a live load of 900 tons, the equivalent dead load would be $500 + (2 \times 900) = 2300$ tons.

The Breaking Load for any structure or piece of material is that dead load which will just produce fracture in the structure or material.

The Working or Safe Load is the greatest dead load which the structure or material can safely be permitted to bear in practice.

[1] The small italic letters in Fig. 447 may be ignored for the present. They are explained in Part IV. The numbers in Fig. 448 are explained at p. 371.

The Breaking Stress is that caused by the breaking load; it is sometimes called the *ultimate stress.*

The Working Stress is that caused by the working or safe load; it is sometimes called the **Limiting or Safe Stress.**

It is evident that structures intended to stand must not be subjected to breaking loads or breaking stresses, but only to safe loads and working stresses (see Table, p. 356).

The Factor of Safety is the ratio in which the breaking load or stress exceeds the working load or stress.

That is, it is the figure by which the breaking load or stress is divided to obtain the working load or stress.

Thus if the breaking tensile stress of a bar of iron is 20 tons per square inch, and it is subjected to a working stress of only 5 tons, the factor of safety is $\frac{20}{5}=4$.

Beams supported at Ends, fixed at one or both Ends, or continuous, and Cantilevers, to know which Parts of the Beam are in Compression and which in Tension.

Supported Beams.

BEAM SUPPORTED AT BOTH ENDS WITH BREAKING LOAD IN THE CENTRE.—A rectangular wooden beam, supported at the ends, when subjected to a concentrated load greater than it can bear breaks as shown in Fig. 449.

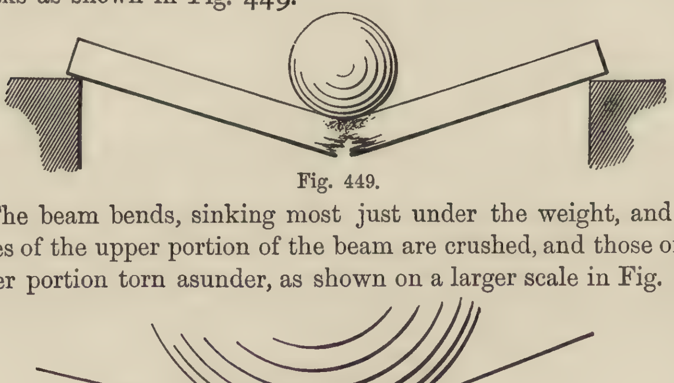


Fig. 449.

The beam bends, sinking most just under the weight, and the fibres of the upper portion of the beam are crushed, and those of the lower portion torn asunder, as shown on a larger scale in Fig. 450.

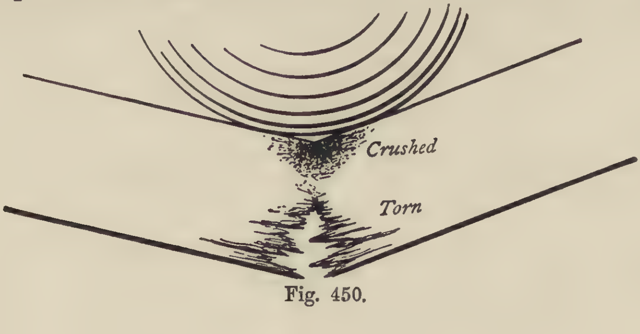


Fig. 450.

Beam supported at both Ends and with a uniformly Distributed Load.—A load uniformly distributed over the beam would produce rupture in the same way, but that the form of the beam before rupture would be slightly different.

A Beam supported at both Ends and subject to a Safe Load—that is, one much smaller than is required to break it—

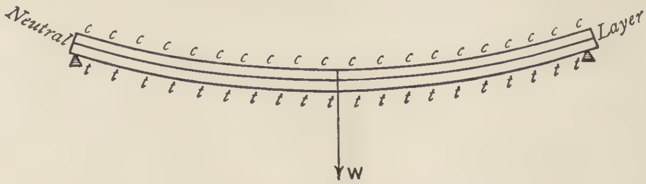


Fig. 451.

will bend to a certain extent, and the fibres of the upper part of the beam will be in compression, and those of the lower part in tension, as shown in Fig. 451. There is a layer between the upper and the lower fibres, in which there is neither compression nor tension, which is called the *neutral layer.*

A Cantilever, however it may be loaded, has the upper fibres in tension and the lower in compression, as shown in Fig. 452.

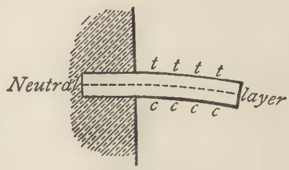


Fig. 452.

Fixed Beams.

A Beam fixed at both Ends—that is, so fixed that the ends cannot tilt up when the beam is loaded—is shown in Fig. 453.

Such a beam is in the condition of two cantilevers, A*f* and B*i*, carrying a beam *fi* between them, which is supported at its ends *f* and *i* by hanging from the ends *f* and *i* of the cantilevers.

From the figure it will be seen that the upper portion of the beam is in tension from A to *f* and from B to *i*; the remainder from *i* to *f* is in compression.

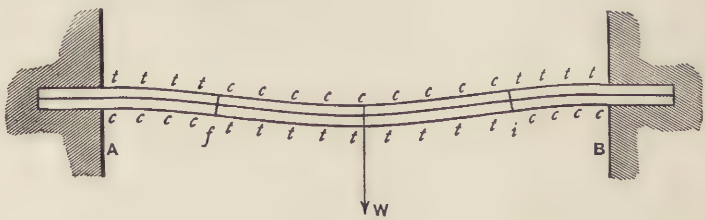


Fig. 453.

The lower portion of the beam is under compression from A to f and B to i, the central portion if being in tension.

It will be noticed that at the points i and f the nature of the stress in each case changes; i and f are called the *points of contra-flexure,* and their distances from A and B depend upon the form of section of the beam, and the distribution of the load, etc. Roughly speaking, the points of contraflexure are generally distant about $\frac{1}{4}$ of the span from the abutments.

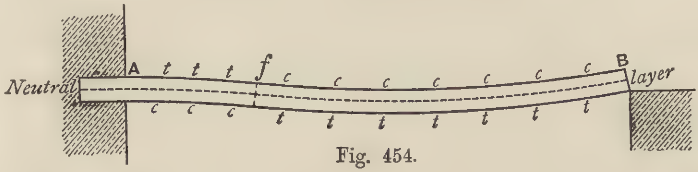


Fig. 454.

A Beam fixed at one End and supported at the other (Fig. 454) is like a combination of a cantilever Af and a supported beam fB; and the portions in tension and compression respectively are shown by the letters $t\,t\,t$ and $c\,c\,c$.

A continuous Beam is one that extends without break in itself over two or more spans.

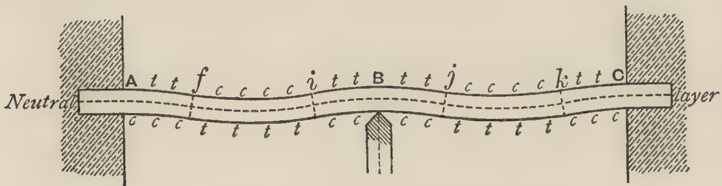


Fig. 455.

If the ends are fixed the compressions and tensions will be as shown by $c\,c\,c$ and $t\,t\,t$ in Fig. 455, resembling those of two fixed beams.

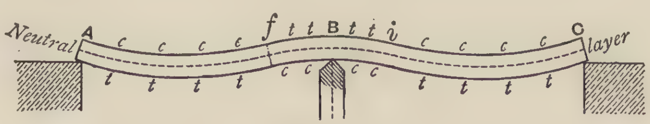


Fig. 456.

If the ends are supported the stresses will be as shown in Fig. 456, the arms in each span being like those of a beam fixed at one end and supported at the other. (Fig. 454.)

Difference in Strength of a Girder carrying a given Load at its Centre or Uniformly Distributed.

On Beams.—A beam that can bear a given load concentrated

at its centre can bear twice that load uniformly distributed over its length.

Thus if the beams in Figs. 444, 445 are similar, and the one in Fig. 444 could bear a concentrated load of 400 lbs., that in Fig. 445 could bear a distributed load of 800 lbs.

On Cantilevers.—Similarly a cantilever that can just bear a given load suspended from its outer end can bear twice that load if it is distributed over its length.

Difference in Strength between Beams of uniform Section supported at both Ends and those fixed at both Ends, or fixed at one End and supported at the other.

A beam fixed at both ends, with a concentrated load at the centre is *twice* as strong as the same beam supported at both ends and similarly loaded.

A beam fixed at both ends, with a uniform load throughout its length is $1\frac{1}{2}$ times as strong as the same beam supported at both ends and similarly loaded.

A beam fixed at one end, and supported at the other, with a concentrated load in the centre is $1\frac{1}{3}$ times as strong as the same beam supported at both ends and similarly loaded.

A beam fixed at one end and supported at the other, with a uniform load throughout its length is of the same strength as the same beam supported at both ends and similarly loaded.

Best Forms for Struts, Ties, and Beams, such as floor joists exposed to transverse Stress.

Best Form for Struts.

Timber Struts should be rectangular in section, and of the same section throughout.

Cast-Iron Struts may be of these cross sections, and tapering in their length, widening from one end to the other as in a column, or from both ends.

Fig. 457.

Fig. 458.

Mild Steel or Wrought-Iron Struts are often of these cross sections.

a

Fig. 459.

b

Fig. 460.

c

Fig. 461.

d

Fig. 462.

e

Fig. 463.

f

Fig. 464.

g

Fig. 465.

Of these *a*, *b*, *d*, and *e* are simple rolled sections, *c* and *f* would be built up, *g* consists of flat bars kept apart by cast-iron distance pieces. Fig. 466 is an elevation of *g*, for the other forms the section is uniform throughout the length of the strut; *g* is useful for struts of small roofs.

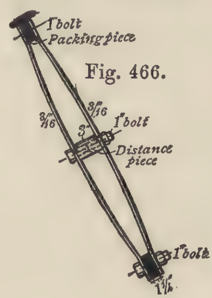


Fig. 466.

Long Struts or Compression Bars are those which are so long in proportion to their width that they fail by bending before crushing.

Short Struts or Compression Bars are those which do not bend under the load, but fail by actual crushing.

Long Struts fixed at the Ends are theoretically stronger than those of which the ends are hinged or rounded. If both ends are fixed they are theoretically 3 times, if one end only is fixed, $1\frac{1}{2}$ times, as strong.

Best Form for Ties.

Any cross section consistent with proper end connections is suitable for a rod or bar in tension whether it be made of timber or wrought iron. Cast iron should never be used for ties.

Best Form for Beams subject to Transverse Stress.

Timber Beams may be of rectangular cross section uniform throughout their length. The deeper they are the better both for strength and stiffness.

Iron Girders are of a section roughly resembling an I, the upper and lower horizontal portions are called the *flanges*, and the upright portion the *web.*

Cast-Iron Beams should have a cross section in which the lower flange to resist tension should have an area from four to six times as great as that of the upper flange which is to resist compression (see Parts I. and IV.)

Fig. 467 shows a section with flanges having areas as 6 to 1, and Fig. 468 with flanges as 4 to 1.

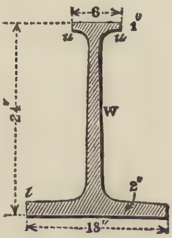


Fig. 467.

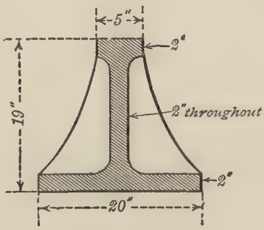


Fig. 468.

And Figs. 469 to 472 show plans and elevations of cast-iron girders for uniformly distributed loads.


Fig. 469.

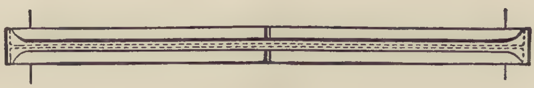


Fig. 470.

The flanges are sometimes made to differ in thickness as in Fig. 467, the web tapering from one to the other, or the metal may be of equal thickness throughout as in Fig. 468.

ELEVATION.

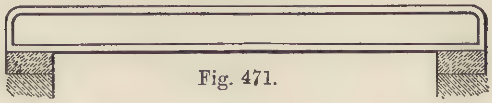


Fig. 471.

PLAN

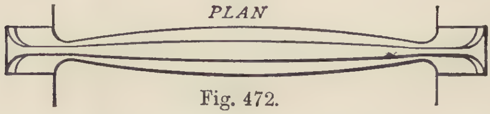


Fig. 472.

Figs. 469, 470, are the elevation and plan of a girder of uniform width, the depth being varied according to the stress to be borne. Figs. 471, 472, are the elevation and plan of a girder of uniform depth, the width of the flanges being varied to suit the stress.

Rolled Joists of steel or iron are of uniform section like Fig. 473 throughout, the flanges being similar and of equal area.

Fig. 473.

Plate Girders are also of a general I form, built up with a plate and angle irons, riveted together as in Figs. 474-476, or, where additional strength is required, with one or more plates in the flanges (one plate is shown in Fig. 476), and stiffeners to support the web.

Section.

Fig. 474.

Elevation.

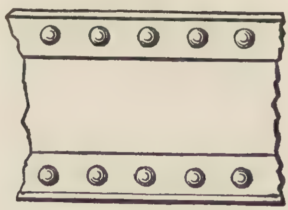


Fig. 475.

Section.

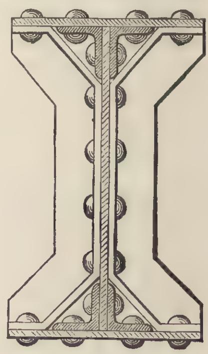


Fig. 476.

In the ordinary kinds of Wooden or Iron Roof Trusses and Framed Structures of a similar description to distinguish the Members in Compression from those in Tension.

There is no very short and simple method for ascertaining

whether the members of a truss are in tension or compression under a given load in any position.

The information can be easily obtained, but the methods employed cannot be explained in these very short notes. They are fully explained in Part IV.

When the loads vary from time to time in position, a member which may with one position of the loads be in tension may with another position of the load have no stress upon it, or even one of an opposite nature.

Thus in an ordinary king-post roof (see Fig. 481) the wind blowing from the right causes a compressive stress upon the strut on that side, but no stress whatever on the other strut, and when the wind is from the left, the stresses on the struts are just reversed.

The student can, however, easily learn and carry in his head the nature of the stresses to which each member of a roof truss is practically subjected.

In Plate IV. Part I. and in Figs. 477 to 482, which give various forms of roof trusses, each of the members shown in thick lines is in compression, and each of those shown in thin lines is in tension, under all loads that can practically come upon the roof, such as the weight of the roof, of snow lying upon it, and the pressure of the wind upon both sides in turn.

Roofs Generally.

Members in Compression.—Generally speaking all rafters, struts, straining beams, etc., are in compression.

Members in Tension.—All king posts, queen posts, and rods, and all tie beams or tie rods are in tension.

Members under Transverse Stress.—Principal rafters loaded by purlins or roof-covering along their length, between the points at which they are supported, as in Fig. 481, are subject to transverse stress as well as compression, and tie beams carrying ceiling joists are also subject to transverse stress.

Timber Roofs.—Figs. 477 to 482 give skeleton diagrams of ordinary roof trusses (see also Plate IV. Part I.)

Fig. 477.

Fig. 478.

Couple Roof (Fig. 477) *and Tied Couple Roof* (Fig. 478).—The rafters are in compression, and the tie in Fig. 478 is in tension.

Fig. 479.

Fig. 480.

Collar Beam Roof.—In this, so long as the walls stand firm (Fig. 479), the beam is a strut and supports the rafters, but if the walls are weak and give way, the beam becomes a tie as shown in Fig. 480.

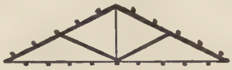


Fig. 481.

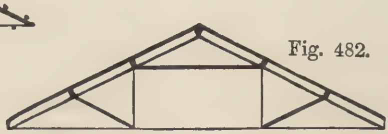


Fig. 482.

King-Post Roof and Queen-Post Roof (Figs. 481, 482).—Nothing need be said about these, except that in Fig. 481 the principal rafters being loaded by the roof-covering between their points of support are subject to transverse stress, as well as the compression upon them, and the tie beam being loaded by the ceiling is also subject to transverse stress as well as tension.

When the purlins are only at the points at which the principal rafter is supported, as in Fig. 482, it is not subject to transverse stress, nor is the tie beam, where there is no ceiling.

Other Framed Structures.

Trussed Beams.—The diagrams, Figs. 483, 484, show by thick lines the members in compression, and in thin lines the members in tension in trussed beams (see Parts I. and IV.)

Fig. 483.

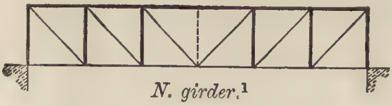
Fig. 484.

These will be the same in nature though not in amount, whether the load be distributed along the upper surface or concentrated at points.

When the load is distributed between the points where the bracing joins the upper beam, the latter is of course subject to transverse stress as well as to compression.

Warren girder.
Fig. 485.

Lattice girder.
Fig. 486.



N. girder.[1]
Fig. 487.

Cross braced N. girder.[1]
Fig. 488.

Braced Girders.—Figs. 485 to 488 are common forms of braced girders, and they show by thick lines the members in compression, and by thin lines the members in tension, when the girders are carrying loads uniformly distributed along the lower flange or at the points where the braces join that flange.

The stresses will be similar in character when the load is on the upper flange, but in Fig. 487 an additional bar will have to be introduced as dotted, and it will be in compression.

Such girders are frequently suspended between their abutments from the ends of their upper flanges; in such a case the construction at the ends of the girder is slightly different, but the nature of the stresses is practically the same as shown in the Figures.

In the case of a concentrated or uniform load upon any part of a beam supported at both ends to ascertain the proportion of the load transmitted to each point of support.

CONCENTRATED LOAD IN CENTRE OF BEAM.—If a concentrated

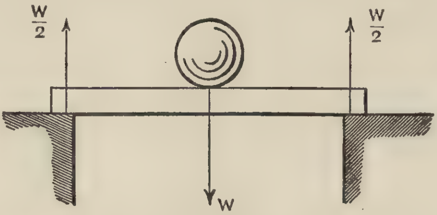


Fig. 489.

weight W be placed upon the centre of a beam supported at the ends, then half the weight is borne at each end. Thus in Fig. 489 half the weight W is borne on each abutment.

LOAD UNIFORMLY DISTRIBUTED OVER WHOLE LENGTH OF BEAM.—If a load, 8 w etc., Fig. 490, is uniformly distributed over a

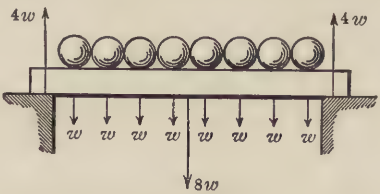


Fig. 490.

[1] Sometimes called *Whipple-Murphy* girder.

beam, then again half the load (in this case 4 w) is borne by each abutment.

Weight of the Beam itself.—The weight of the beam itself is like a uniform load, and half that weight is supported by each abutment.

Load at any Point of Beam.—The proportion of the load borne by each support may, avoiding formulas, be found by the following rule.

Rule.—*If a load is placed anywhere on a beam supported at both ends, then the proportion of the load borne by either support is equal to the load, multiplied by the distance from its centre of gravity to the other support, and divided by the length of the beam between the supports.*

Concentrated Load.—Thus in Fig. 491 the load W is 400 lbs., and it is distant 5′ 0″ from A and 10′ 0″ from B.

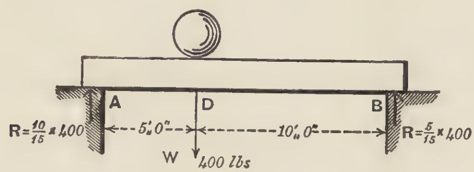


Fig. 491.

The proportion of W borne at A is equal to $\frac{\text{W} \times \text{distance DB}}{\text{Length AB}}$,

$$i.e. = \frac{400 \text{ lbs.} \times 10 \text{ feet}}{15 \text{ feet}} = 266\tfrac{2}{3} \text{ lbs.}$$

The proportion of W borne at B is equal to $\frac{\text{W} \times \text{distance DA}}{\text{Length AB}}$,

$$i.e. = \frac{400 \text{ lbs.} \times 5 \text{ feet}}{15 \text{ feet}} = 133\tfrac{1}{3} \text{ lbs.}$$

Reaction.—The proportion of the load borne by each support is called the reaction at that support. In Fig. 491 the reaction at A is shown as $R = \frac{10}{15} \times 400$. Reaction at B, $R = \frac{5}{15} \times 400$.

Load uniformly distributed over Central Part of the Length of a Beam.—In this case the load may be considered as acting through its centre of gravity, and then its reactions are found as in the case of a concentrated load at the centre.

Thus if the load were uniformly spread over an equal distance on each side of the centre of the beam as in Fig. 492, then half the load is borne by each support.

Similarly when the uniform load is made up of a number of weights 4 w, then each support takes 2 w.

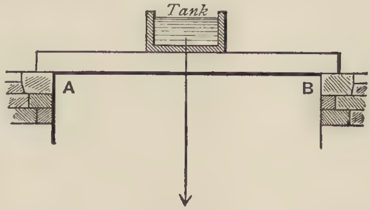


Fig. 492.

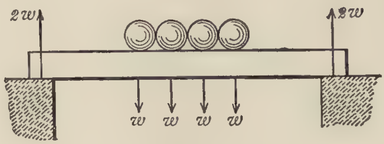


Fig. 493.

LOAD UNIFORMLY DISTRIBUTED OVER ANY PART OF THE LENGTH OF A BEAM.

In this case the load is equivalent to a single concentrated load at the centre of gravity of the distributed load.

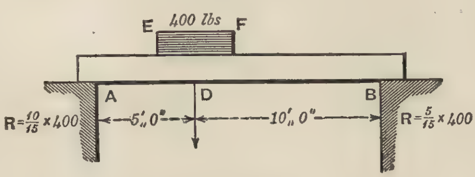


Fig. 494.

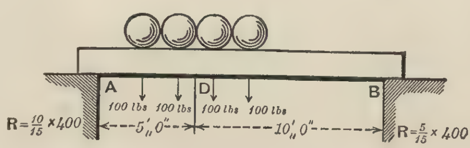


Fig. 495.

Thus in Fig. 494 the weight of the tank which is distributed over E F may be taken as acting at D through its centre of gravity.

The reactions are then just the same as in the case illustrated in Fig. 491.

Again when the distributed load is made up of separate weights as in Fig. 495, they may be considered as acting through their common centre of gravity, and the reactions are again the same as shown in the Fig. 491.

ANY NUMBER OF CONCENTRATED LOADS ON A BEAM.—When the loads are unequal, and placed unsymmetrically, the reaction of each at each support is found in turn. The total reaction at either support will be the sum of the reactions produced by each weight at that support.

Take a simple case, with only two unequal weights placed unsymmetrically, as shown in Fig. 496.

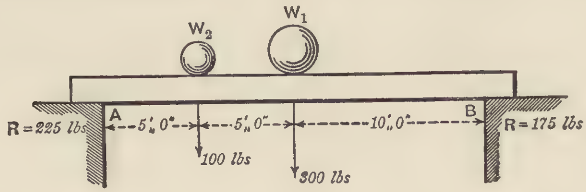


Fig. 496.

Applying the rule given above for a single weight not in the centre of the beam, we have—

	at A	at B
Reaction produced by W_1	. $\frac{10}{20}W_1 = \frac{10}{20} . 300 = 150$	$\frac{10}{20}W_1 = \frac{10}{20} . 300 = 150$
" " W_2	. $\frac{15}{20}W_2 = \frac{15}{20} . 100 = 75$	$\frac{5}{20}W_2 = \frac{5}{20} . 100 = 25$
Total reaction produced by $W_1 + W_2$, *i.e.* by $300 + 100$ lbs.	225 lbs.	175 lbs.

N.B.—*The consideration of bending moments, moments of resistance, shearing stresses, etc., and calculations for strength, even for the simplest beams, does not form a part of this volume but is entered upon in Part IV.*

APPENDIX I.

GLOSSARY OF ELECTRICAL TERMS

The following are practical and popular, as distinguished from scientific and legal, definitions of terms in frequent use.

Alternating Current.—A current whose direction is reversed several times a second (symbol A.C.).

Alternator.—A dynamo developing alternating currents.

Ampère.—The unit of current = the current forced through a resistance of one ohm by one volt (symbol Amp.).

Calorie.—A unit of heat. 1 calorie = 0·003968 British thermal units.

Choking Coil.—A coil of wire in an alternating circuit, acting like a resistance in a continuous current circuit.

Circular Mill.—A circle whose area is one square mill. (See *Mill.*)

Condenser.—An appliance for adding electrical capacity to a circuit.

Continuous Current.—A current flowing continuously in one direction (symbol C.C.). Also called *Direct Current* (symbol D.C.).

Continuous Current Transformer.—A machine having two commutators and two armature windings on one core, for transforming the voltage of supply.

Coulomb.—The unit of quantity representing the amount of electricity conveyed by one ampère per second.

Cycle.—In alternating currents, a period during which the current starting from zero attains its maximum positive and negative values, and returns to zero.

Dielectric.—An insulating substance.

Direct Current.—Same as continuous current (symbol D.C.).

Dynamo.—A machine which converts mechanical into electrical energy.

Earth.—A term signifying the potential of the earth. The act of imparting the potential of the earth to any conductor or apparatus.

Economy Coil.—A coil for suppyling arc lamps on alternating current circuits with steady current at the proper voltage.

Electrolysis.—The splitting-up of a liquid into its constituent elements by means of electricity. The corrosive action of stray currents on water or gas pipes.

Electromotive Force.—The force, measured in volts, which tends to force a current through a resistance (symbol E.M.F.). See *Potential Difference*, *Pressure*, *Tension*, and *Voltage.*

Energy.—The capacity to do work. Commonly measured in watt-hours. The commercial unit is 1000 watt-hours = one Board of Trade Unit.

Farad.—The unit of capacity. A condenser of one farad capacity will be charged to the potential of one volt by one coulomb.

Feeder.—A cable run from the generating station to a point of the distributing network, in order to maintain the voltage.

Frequency.—The number of cycles per second in alternating current. Also called *Periodicity.*

Henry.—The unit of inductance. The amount of inductance in a circuit when the current is changing at the rate of one ampère per second, and producing a difference of pressure of one volt.

Horse-Power.—A practical unit of work; one horse-power (H.P.) = 33,000 foot-pounds per minute. Brake horse-power (B.H.P.) = the available horse-power at the pulley. Electric horse-power (E.H.P.) = 746 watts. Indicated horse-power (I.H.P.) = the calculated horse-power from the mean steam pressure on the piston, *i.e.* the horse-power put into an engine. Nominal horse-power (N.H.P.) = a purely arbitrary unit varying with different makers.

Impedance.—The equivalent to resistance in alternating current circuits, where Ohm's law does not hold good.

Joule.—The unit of energy = the work done in one second when one ampère flows under a potential difference of one volt, or when one coulomb is transferred through a potential difference of one volt.

Kilowatt.—One thousand watts (symbol KW.)

Load.—The work being done by any converter of energy.

Megohm.—One million ohms. The practical unit of insulation resistance (symbol Ω).

Mho.—The unit of conductivity. The reciprocal of the ohm.

Mill.—One mill = $\frac{1}{1000}$ inch. (See *Circular Mill.*)

Ohm.—The unit of electrical resistance.

Parallel.—To connect in parallel is to connect two or more lamps or other appliances across the main leads of supply.

Period.—The time taken for a complete cycle in an alternating current.

Periodicity.—See *Cycle.*

Phase.—In alternating currents, the fraction of the whole period which has elapsed since the commencement of the period.

Pole.—The termination or end of a magnet.

Polyphase.—Having two or more phases. A polyphase current is one compounded of two or more single-phase currents; the phases being 180° apart in a two-phase current, 120° apart in a three-phase current, and so on.

Potential Difference (symbol P.D.). The difference of potential between two conductors of an electrical circuit, or two poles of any electrical apparatus.

Power.—The rate of doing work.

Pressure.—Potential difference.

Relay.—An instrument placed in series with a main circuit, which brings into action a local circuit. In bell, telephone, and similar circuits it is practically an automatic electro-magnetic switch.

Resistance.—The ratio of electromotive force in a conductor to the current produced (symbol R.). The unit is the ohm.

Resistance.—A coil of wire for the regulation of voltage in a continuous current circuit.

Secohm.—The unit of self-induction, another name for the *henry.*

Secondary.—Secondary coil or winding.

Series.—To join in series is to connect lamps or electrical appliances on a circuit, one after the other.

Short Circuit.—An unintentional connection bridging a source of electric supply with a low resistance.

Shunt.—A by-pass for current.

Solenoid.—A coil of wire used for electro-magnetic purposes.

Standard Candle.—A spermaceti candle, $\frac{7}{8}$ in. diameter, weighing $\frac{1}{6}$ lb., and burning 120 grains per hour.

Synchronism.—The concurrence of the movement of two instruments, such as clocks, meters, etc.; or the phase coincidence of two alternators, which are then said to be in step.

Tension.—Potential difference.

Volt.—The unit of electromotive force (symbol V.).

Voltage.—The difference of potential between two conductors of a circuit, or two poles of any electrical apparatus.

Voltampère.—A watt.

Watt.—The practical unit of electrical power. Volts × ampères = watts.

Watt-hour.—The practical unit of electrical energy.

APPENDIX II.

GENERAL RULES RECOMMENDED BY THE INSTITUTION OF ELECTRICAL ENGINEERS FOR WIRING FOR THE UTILISATION OF ELECTRICAL ENERGY.

Revised 1903.

1. These rules embody the requirements and precautions which the Institution has framed to secure satisfactory results with supply at a pressure not exceeding 500 volts if continuous or 250 volts if alternating. They are intended to include only such requirements and precautions as are generally necessary, but they are neither intended to take the place of a detailed specification, nor to instruct untrained persons.

2. Notice of the proposed introduction of wiring should in all cases be given to the Fire Offices insuring the risk, and to the suppliers of the electrical energy if such is to be obtained from an external source.

General Arrangement.

3. Conductors must radiate from distributing centres, and in large systems from those centres to sub-centres, so that no sub-circuit carries more than 5 ampères up to 125 volts, or more than 3 ampères from 125 to 250 volts, for incandescent lighting.

4. When protected from mechanical injury by hard-metal tubes or conduits, conductors even of opposite polarity may be "bunched," and when carrying small currents from sub-centres, as in paragraph 3, they may, if without joints, be "bunched" even when the protecting tubing or casing is non-metallic. If the supply is alternating and the protection metallic, conductors must be bunched so that the sum of the currents passing is zero.

5. When one of the main conductors of a system of supply is earthed, no interruption of the current by any mechanical device is permitted in a conductor connected to the earthed main that does not also, and simultaneously, break circuit on the non-earthed conductor. Hence, to insure the current being interrupted simultaneously on both the earthed and the non-earthed wires, no switch that is not linked to another switch on the non-earthed conductor may be inserted in any conductor connected to an earthed main.

6. No fuse may be placed in the neutral conductor of a "three-wire" system. This does not prevent the use of a disconnecting link in the neutral for testing purposes, but fuses must be placed on both conductors of two-wire circuits branching therefrom.

7. Every system must be controlled by linked main switches, which must be placed as near to the entry of supply to a building as circumstances permit, and which must be easily accessible. Subject to paragraph 6, the system must also be protected by main fuses.

8. Every sub-circuit must be protected on both poles by a fuse; and no single-pole switch may be inserted in the earthed side of a system.

9. When the wiring is such that one conductor is uninsulated at all points—such as a bare return to a concentric system—no switch or fuse may be placed in that conductor, and the said conductor must be efficiently earthed.

10. When the supply is from all three conductors of a *three-phase* system, each conductor must be protected by a fuse and the whole controlled by three linked switches.

11. When the pressure between outer conductors of a three-wire main exceeds 250 volts, the circuits connected to opposite sides of the neutral conductor must be so disposed that a person cannot simultaneously touch two points respectively in contact with the outer conductors.

12. Conductors conveying currents at pressures exceeding 250 volts must be completely enclosed in strong metallic sheathing or tubing efficiently connected to earth, and such sheathing or tubing must be electrically continuous throughout its length.

13. No switch, cut-out, connector, or other electrical appliance, may be mounted directly upon any surface of a condensing or humid nature, such as masonry, brickwork, cement, or plaster—but must, in addition to its own mount, be fixed upon a base block rendered impervious to moisture.

14. Branch fuses must be grouped together in accessible positions in sight, and should be symmetrically placed and labelled for each circuit.

15. Contact between insulated conductors and gas-pipes, or metals in contact therewith, must be prevented by non-conducting incombustible distance-pieces.

16. Gas-pipes must never be used to obtain an earth connection.

17. Switches and fuses, not in an engine-room or compartment specially arranged for the purpose, must be covered.

Conductors—Conductivity and Size.

18. The sectional area of conductors (see Table) must be greater than that determined by the heating effect of the current required for the maximum number of lamps, or other current-using apparatus, that can be used simultaneously on the circuit.

19. The size of conductors within a building will, subject to paragraph 18, be determined by the permissible drop in volts, which should not exceed 2 per cent on lighting circuits.

20. Copper conductors should be of soft copper, and should have a conductivity not less than 100 per cent as compared with Matthiessen's[1] standard; and where sulphur compounds are present in any part of the insulation the copper in contact with the insulation must be protected therefrom by tinning or otherwise.

21. The sectional area of a copper conductor must not be less than that of No. 18 S.W.G. wire, with the exception of the case of flexible cord conductors and wires for fittings, when the sectional area must not be less

[1] See Appendix to these Rules, p. 387.

than that of a No. 20 S.W.G. wire. All insulated copper conductors having a greater area than that of a No. 14 S.W.G. wire must be stranded.

22. The table appended shows the sizes of copper conductors which will safely carry currents up to 740 ampères, and the length in yards of single conductor in circuit for each volt of fall of potential when the maximum current is in use.

Conductors—Insulation.

23. Conductors must be specially insulated with material which does not deteriorate at the highest temperature to which it will be subjected ; for instance, rubber must not be allowed to exceed 130° F., or paper—or fibre—insulation 170° F. In specially hot places the conductors should be so large that the electric heating is almost nil.

24. The insulation on any conductor other than a flexible cord must be throughout either—

(*a*) A dielectric which is impervious to moisture and only needs mechanical protection. ("Dielectric" does not include braiding or taping.) Or

(*b*) A dielectric which must be kept perfectly dry, and therefore needs to be encased in a waterproof sheath, generally of soft metal, such as lead, drawn closely over the dielectric.

25. The radial thickness of vulcanised rubber must be not less than 30 mils plus one-tenth of the diameter of the conductor (see Table, column 3). The radial thickness of dielectrics of Class (*b*) must be not less than that given in the Table, column 4. The dielectric must not soften sufficiently to allow decentralisation at a lower temperature than 170° Fahr.

26. The dielectric of Class (*a*) must be thoroughly damp-proof, and that of Class (*b*) must be enclosed in a sheath of ductile material entirely impervious to moisture, which, if metallic, must be electrically continuous throughout and connected to earth.

27. The dielectric must be such that when a test-piece of the insulated conductor has been immersed in water for twenty-four hours it will, while still immersed, withstand 2000 volts for ten minutes between the conductor and the water. Prior to immersion the test-piece must have been bent six times (three times in one direction and three times in the opposite direction) round a smooth cylindrical surface not more than twelve times the diameter of the finished cable.

28. The minimum insulation resistance should be that given in Column 12 of the Table for vulcanised rubber, and that in Column 13 for Class (*b*), the test being made at 60° F. after one minute's electrification at 500 volts, and after the test-piece has been immersed in water for twenty-four hours. This resistance must not fall more than 10 per cent after seven days' immersion.

29. Conductors insulated as in Class (*a*) may be protected by braid or taping, prepared so as to resist moisture. Unless fixed in sight and out of reach of injury, all conductors must, further, be protected by a strong covering; and this, in damp situations, must consist of water-tight, incombustible tubes, which, if of metal, must be electrically continuous throughout and connected to earth. Means must be provided to prevent the accumulation within the tubing of water arising from condensation or other sources.

Sharp bends or elbows must be avoided, corners being turned by smooth-bore round bends or suitable boxes.

30. The exposed ends of conductors, with dielectrics of Class (*b*), where they enter the terminals of switches, fuses, and other appliances, must be protected from moisture which might creep along the insulating material within the waterproof sheath.

31. Concentric conductors should in all respects conform to the requirements herein laid down for single conductors; the insulation resistance of the dielectric separating the two conductors must be that given in the Table for single conductors having the same diameter as the inner conductor. The insulation resistance of the dielectric on the outer conductor where insulated, must be that given in the Table for single conductors of the same outside diameter.

32. When the mains are earthed at one point, the outer conductor of a concentric system is the conductor to be connected to the earthed main.

33. In applying the bending test to concentric conductors, the diameter of the cylinder used should be not more than twelve times the diameter of the finished cable.

34. Flexible conductors, *i.e.* those made up of a number of wires not larger than No. 35 S.W.G., which are then insulated, may only be used for attachment to portable appliances or pendants or for sub-circuits when visible throughout their length and spaced from walls by porcelain insulators. For the wiring of fittings a strand composed of three wires of No. 25 S.W.G. may be used. The insulating material used as the dielectric must be either pure rubber or vulcanised rubber of the best quality. If pure rubber be used, it should be laid on in two layers, care being taken that these break joint. The radial thickness of the dielectric must not be less than 16 mils for pressures up to 125 volts, or 20 mils for pressures from 125 to 250 volts. The covering must be such that a test-piece not less than one yard in length cut from the conductor will withstand a pressure of 1000 volts alternating at a frequency of from 40 to 100 periods per second applied for ten minutes between the test-piece and a similar test-piece twisted together with it, the pieces being subjected during the test to the vapour arising from a pan of boiling water placed ten minutes before the commencement of the test at a distance not exceeding three feet immediately below it.

Conductors—Joints.

35. Joints in conductors are prohibited except on small wires protected by fuses, viz. 5-ampère fuses on circuits up to 125 volts, and 3-ampère fuses on circuits from 125 to 250 volts. Junction-boxes must be used to connect lengths of larger conductors, and be so constructed that—

(*a*) the conductors cannot be readily short-circuited;
(*b*) the insulation between opposite poles will not readily break or chip;
(*c*) the connections do not heat.

If used in damp places, special precautions must be adopted to exclude moisture.

36. Joints must be mechanically and electrically perfect to prevent heat being generated. All joints must be soldered. Soldering fluids containing acid, or other corrosive substances, must not be used. The insulation of all joints in insulated conductors must be most carefully attended to.

37. In jointing conductors the braiding, tape, or lead must be carefully removed without damage to the dielectric for a sufficient length to insure a thorough union between the dielectric and the material used to insulate the joint. If the insulating material is not waterproof, it must be covered with an impervious sleeve or box, which must make a water-tight joint on each side of the junction. Care must be taken to exclude moisture during the operation.

38. Joints between flexible conductors and permanent wires under flooring or in wood-casing are prohibited.

Joints constitute a source of weakness, and they must, therefore, be accessible, and it is recommended that their positions be indicated by a conspicuous mark.

Buried Conductors in Buildings.

39. Conductors buried in cement or plaster must be provided with protection of sufficient strength to resist a nail.

40. Conductors passing through walls or fire-resisting floors must be provided with additional protection, such as a porcelain or other incombustible tube, which must be filled up with some chemically inert incombustible material so as to prevent the spread of fire through these openings. When the end is outside the building it should be bell-mouthed and turned downwards.

Conductors—Wood Casing for.

41. Wood casing must not be—

(*a*) buried in plaster or cement, nor exposed to moisture;
(*b*) used in damp places;
(*c*) run immediately below water-pipes unless efficiently protected from drip.

Conductors—Precautions at Points of Connection.

42. Where conductors are connected to switches, fuses, junction-boxes, or other appliances, the whole of the separate wires forming the stranded or flexible conductor must make contact with the terminal so that no loose wire or strand can project. The dielectric must not be bared back farther than to allow the conductor to enter the terminals properly, and the ends of the insulation, Class (*b*), should be sealed.

43. The braiding, lead, or other covering to the dielectric must be cut back from the end of the insulating material and waterproofed. In damp places the strands of conductors, Class (*b*), should be soldered to prevent moisture creeping along the copper beneath the insulation.

44. Conductors of larger section than 7/18 must be soldered to proper lugs for connection. Where there is any possibility of strain on the lugs they must be mechanically attached in addition to the soldering.

Switches.

45. Every switch, whether fixed separately or combined with lampholders or fittings, must, except as provided in paragraph 17, be encased, and comply with the following requirements:—

(*a*) Overheating must not take place at the point of contact or elsewhere, when the full current flows continuously.

(*b*) When being switched off it must not be possible to form a permanent arc. Switches should be tested at pressure and current 50 per cent in excess of that which will be used on the circuits for which they are intended.
(*c*) It must be incapable of remaining in partial contact.
(*d*) The base must be of incombustible non-conducting and moisture-proof material.
(*e*) The cover must be of incombustible material, and must be either non-conducting, or of rigid metal, and clear of all internal mechanism.
(*f*) Where the pressure exceeds 250 volts, covers must be of metal and must be earthed.
(*g*) Handles must be insulated and so arranged that the hand cannot touch live metal.
(*h*) It must not contain a fuse.

Fuses.

46. Every fuse must be encased, except as provided in paragraph 17, and comply with the following requirements :—

(*a*) That no overheating can take place in any part when the full current flows continuously.
(*b*) That it shall effectually interrupt the current when a short-circuit occurs, and also when the current through it exceeds the working rate by 100 per cent, the current flowing under the normal pressure in both cases.
(*c*) The base of the fuse must be of incombustible, non-conducting, and moisture-proof material.
(*d*) The cover must be of incombustible material, and must either be non-conducting or of rigid metal lined with insulating incombustible material. It must be kept clear of all the internal mechanism. When the fuses are of the open type and grouped together, the case of the distribution board will be a sufficient protection provided the distance from cover to fuse exceeds two inches.
(*e*) Fuses must not be placed in wall-sockets, ceiling roses, lampholders, or switch covers.
(*f*) The fusible metal must be of such size that no conductor protected by it can possibly exceed the temperature specified in paragraph 23.

47. Separate single fuses, and not "double-pole" fuses, must be used on circuits on which the pressure exceeds 125 volts.

48. Fuses may be considered too large if they are not warm to the touch on full load, and too small if they hiss when moistened.

49. *Note.*—It is recommended that hard metal be used for fuses ; and that if soft wire is used, it should be soldered to hard-metal contacts.

Connectors: Wall- and Floor-Plugs, etc.

50. All connectors should be capable of withstanding a test at a pressure and current 50 per cent in excess of that for which they are intended. In damp places special water-tight connectors must be used. In cases where the fixed part of the connector is attached to a floor it must be so arranged

that no dust or water can accumulate in the cavity, and that all contacts are well below the floor-level, or covered to prevent any possibility of danger from contact with carpets.

51. No connector may contain a fuse.

52. Connectors must be constructed so that they cannot be readily short-circuited. Clearances should be such that an arc cannot be started if the connector is pulled out at the time that the current is flowing. The insulation used between opposite poles should be such that it will not readily break or chip.

53. Flexible cord conductors for portable fittings must end in a connector.

54. Every portable current-consuming device must be independently controlled by a switch on the live side of the connector.

Ceiling Roses.

55. Every ceiling rose must comply with the following requirements :—

(*a*) The base must be of incombustible, non-conducting and moisture-proof material ;

(*b*) The cover must be of incombustible material, and must be either non-conducting or of rigid metal, and clear of all internal mechanism ;

(*c*) Unless it, or its base, form part of the sheathing as in paragraph 12, it must not be attached directly to a plastered surface, but must be mounted on a prepared block ;

(*d*) Its terminals must be relieved of the direct pull of the attached conductor and fitting, and be so arranged that no short circuit can take place ;

(*e*) It must not contain a fuse.

Switch and Distribution Boards.

56. Main and distribution switch- and fuse-boards must be made of incombustible insulating material insulated, where hygroscopic, by bushes from the supporting framework, and fixed in a dry situation, and be so placed that a fire thereon cannot spread to combustible material.

57. Live metal must be fixed at such a distance from all metal not at the same potential, or be so separated by insulating partitions, that an arc cannot be formed between the metal surfaces.

58. Connections at the back of boards must be made accessible, but, unless protected from acid fumes, must not project into battery rooms. Circuits should be labelled for identification.

59. The cases of instruments, if metallic, must be insulated from the circuits, or, if connected to one pole, they should be protected from the possibility of contact with the other.

60. Every voltmeter with its connecting wires should be protected by a fuse on each pole.

Fittings for Supporting Lamps.

61. Wherever brackets, electroliers, or standards require to have the conductors threaded through tubes or channels formed in the metal work, these must be of ample size and have no sharp angles or projecting edges, which would be liable to damage the insulating material.

62. Where possible, the conductors should be carried without joints

through the fittings to the lamps; but where connections at the fittings are unavoidable, special care must be taken to make the joints equal in conductivity and insulation to the rest of the work.

63. Combined gas and electric fittings must not be used.

64. When disused gas-fittings are adapted for electric light, they must be entirely disconnected from the gas-pipes.

Lampholders.

65. Lampholders must—

(*a*) be entirely incombustible;
(*b*) be insulated from any continuously earthed conduit or sheath not forming part of the circuit;
(*c*) be specially designed if for currents above $1\frac{1}{2}$ ampères;
(*d*) not be hung from flexible cord conductors where exposed to the weather, but be rigidly supported.

66. Switch lampholders should be controlled in groups of ten, or fewer, by a separate fixed wall-switch.

Arc Lamps.

67. Arc lamps must—

(*a*) be guarded by lanterns or globes, which must be arranged to intercept falling particles of carbon;
(*b*) be insulated from their support;
(*c*) be fixed so that their cases cannot come into contact with any metallic object;
(*d*) have their leading-in wires protected from rain;
(*e*) be controlled by linked switches and protected by fuses (see "General Arrangements");
(*f*) not be used in places where inflammable vapours or explosive mixtures of dust or gas are liable to be present.

Incandescent Lamps.

68. Incandescent lamps and their holders—

(*a*) must not be placed in close proximity to inflammable materials; shades made of such materials must be kept free from contact with the lamps by suitable guards; celluloid and other highly inflammable material must not be used for shades;
(*b*) if placed in positions where they are exposed to inflammable vapour or gas, should be enclosed in air-tight fittings of thick glass and have no flexible cord connections.

69. Incandescent lamps of the Nernst type must comply with the regulations of paragraphs 67 (*a*), (*b*), (*c*), (*d*), (*f*), and 68 (*a*).

Dynamos and Motors.

70. Any dynamo or motor rated at more than one-third of a horse-power must—

(*a*) be protected from damp, dust, and mechanical injury;
(*b*) be so placed that no unprotected woodwork or combustible material is within a distance of twelve inches from it measured horizon-

tally, or within four feet measured vertically above it, unless it is of an enclosed type ;

(*c*) if supplied at 250 volts or upwards, have its frame efficiently connected to earth ;

(*d*) if employed in positions exposed to highly inflammable dust or flyings, or where highly inflammable materials are manipulated or stored, be of the enclosed type, without belting or gearing penetrating the casing, with ventilating openings, if any, only in the vertical portions of their casings, protected by two thicknesses of fine-mesh wire gauze set at least a quarter of an inch apart and substantially attached to the casing ;

(*e*) be controlled by linked switches and protected by fuses or circuit-breakers on both conductors ;

(*f*) if a motor, have, in addition to the above, starting gear consisting of a regulating switch and series resistance, the regulating switch being fitted with a magnetic release that will automatically open the circuit should the current be interrupted.

Note.—It is recommended that all shunt circuits of motors be arranged so that the field is excited before the armature is connected, these circuits to be disconnected through a non-inductive resistance or carbon break after the armature circuit is broken.

Resistances.

71. Resistances, whether used in connection with arc-lamps, dynamos, or motors, or for any other purpose, must be—

(*a*) carried on frames or supports and enclosed in cases, the frames, supports, and cases to be of incombustible material efficiently insulated from the resistances ;

(*b*) amply ventilated by means of apertures protected by fine-mesh wire gauze where there is danger of inflammable material entering them ;

(*c*) so proportioned that they cannot rise in temperature more than 240° F., nor the cases containing them more than 130° F., above the temperature of the surrounding air ;

(*d*) so fixed that no unprotected inflammable material is within six inches of the cases containing them, or within twenty-four inches measured vertically above them.

Choking Coils.

72. Choking coils must comply with the rules for Resistances (71, *a*, *b*, and *d*, and 76).

Accumulators and Other Batteries.

73. The room in which accumulators or primary batteries are placed must be well ventilated.

74. Accumulators and batteries must be well insulated from earth, and protected by fuses at all points of connection between the circuit and the regulating cells, unless special precautions are taken to keep the conductors permanently apart by incombustible and non-conducting material.

Transformers.

75. If high-pressure transformers are brought into a building they must—

(*a*) together with their switches and fuse-boxes, be contained in fire- and water-proof structures, and be accessible only to authorised persons;

(*b*) be so protected by suitable apparatus that a leak between the primary and secondary coils shall cut the transformer out of circuit;

(*c*) not under normal full-load exceed a temperature of 170° F.

76. Low-pressure alternating transformers or choking coils must conform with paragraphs 71 (*a*), (*b*), and (*d*), and their temperature must not exceed 170° F.

Electric Cooking Appliances, Radiators, and Heaters.

77. These appliances must be—

(*a*) so constructed and mounted that heat cannot be conveyed to their supports and connections, precautions being taken with regard to their surroundings as in the case of non-electrical heating appliances;

(*b*) protected by a fuse and switch in both conductors, subject to Rule 5, connectors being so arranged that the live end of the coupling is not exposed to accidental short-circuiting or injury.

Testing.

78. The insulation resistance to earth of the whole or any part of the wiring must, if tested previously to the erection of fittings and electroliers, be measured with a pressure not less than twice the intended working pressure, and must not be less in megohms than 30 divided by the number of "points" under test. For this purpose the "points" are to be counted as the number of pairs of terminal wires from which it is proposed to take the current, either directly, or by flexibles, to lamps or other appliances.

79. Current must not be switched on until the following test has been applied to finished work:—

The whole of the lamps having been connected to the conductors and all switches and fuses being on, a pressure equal to twice the working pressure must be applied, and the insulation resistance of the whole or any part of the installation must not be less in megohms than 25 divided by the number of 30-watt lamps. When all lamps and appliances have been removed from the circuit, the insulation resistance between conductors must not be less than 25 megohms divided by the number of 30-watt lamps. For the purpose of this test, every arc light shall be considered as equivalent to 15 lamps, and every motor or heater shall be rated at one lamp per ampère, provided that no motor, heater, or other appliance may be connected to the supply of electrical energy unless the insulation of the parts carrying the current measured, as above, is greater than 500,000 ohms from the frame or case.

80. The value of systematically inspecting and testing apparatus and circuits cannot be too strongly urged as a precaution against fire. Records should be kept of all tests, so that any gradual deterioration of the system may be detected. Cleanliness of all parts of the apparatus and fittings is

essential. In testing, the negative pole should be connected with the conductor under test.

81. No repairs or alterations may be made when the pressure is "on."

Explanation of Table.

82. *Columns 1 and 16* give the size of the conductors in common use. Cables are shown thus:—19/16, viz. 19 wires of number 16 standard wire gauge, or 19/·082″, meaning 19 wires, each of which is ·082 inch in diameter.

83. *Column 2* gives the section of the conductor in square inches.

84. *Column 3* gives the minimum thickness of dielectric as defined in paragraph 25 on vulcanised rubber cables.

85. *Column 4* gives the minimum thickness of dielectric on fibre-covered cables which require to be lead-covered, viz. cables of Class B. Special cables, such as twin or 3-core cables, are not included in this column.

86. *Column 5* gives the safe radial thickness of lead in decimals of an inch for cables of Class B. This column does not apply to vulcanised rubber cables, which may be lead-covered.

87. *Column 6* gives the maximum current for wires insulated with vulcanised india-rubber laid in position within the mechanical protections allowed in the Rules, when the external temperature is higher than 100° F. The current for any conductor under these conditions may be calculated from the formula:—

$$\text{Log } C = 0{\cdot}775 \log A + 0{\cdot}301,$$
$$C = 2A^{0{\cdot}775}$$

(where C = current in ampères, A = area in 1000ths of a square inch).

The maximum rise in temperature will be about 10 degrees Fahrenheit on large sizes.

88. *Column 7* gives the maximum current allowable in any situation for conductors insulated with vulcanised rubber when laid in positions within the mechanical protections allowed in the Rules when the external temperature is normal. The maximum current for any conductor may therefore be calculated from the formula—

$$\text{Log } C = 0{\cdot}82 \log A + 0{\cdot}415,$$
$$\text{or } C = 2{\cdot}6\ A^{0{\cdot}82}$$

89. *Column 8* gives the total length in yards of lead and return of each size of conductor, causing a drop of 1 volt when transmitting the current shown in Column 6.

90. *Column 9* gives the current density in ampères per square inch corresponding to Column 8.

91. *Column 10* gives the maximum allowable current with lead-covered cables, allowing a rise of about 20° F. on large sizes.

92. *Column 11* gives the total length in yards of the conductor (lead and return) for one volt drop when the current in each conductor is that given in Column 10.

93. *Column 12* gives the minimum insulation resistance with vulcanised rubber in mile-megohms. These insulation resistances correspond approximately with those of "300 megohm grade" cables having a specific insulation of 1·4.

94. *Column 13* gives the minimum insulation resistance which is advisable

in practice for fibre-covered cables lead-covered. The insulation resistance between the members of twin-conductors should be not lower than the corresponding insulation resistances in the Table.

95. *Column 14* gives the resistance in Board of Trade ohms of the conductor per 1000 yards.

96. *Column 15* gives the weight of copper conductors of the gauge given in lbs. per 1000 yards.

Definitions of certain Terms used in above Rules.

97. *Bunching of Conductors.*—Conductors are said to be bunched when more than one is contained within a single duct or groove.

98. *Dielectric.*—A dielectric is any material which by its nature or the method of its application to a conductor permanently offers high resistance to the passage of current and of disruptive discharge through itself.

99. *Earthed Conductor.*—A conductor is said to be earthed when it is metallically connected at one or more points to the general mass of the earth.

100. *Linked Switches.*—Linked switches are single-pole switches fixed on conductors of different polarity linked together mechanically so as to operate simultaneously.

101. *Neutral Conductor.*—The neutral conductor of a three-wire system is the conductor which is at a potential intermediate between the potentials of the outer conductors, and is common to all consuming devices.

102. *Outer Conductor.*—The outer conductors of a three-wire system are those between which there is the greatest difference of potential.

Note.—This specialised use of the word "outer" must not be confused with the non-technical use of the word when applied to the conductor of a concentric main which physically surrounds the other conductor or conductors of such main.

103. *Single-pole Switches.*—Single-pole switches are switches interrupting one conductor only of a circuit.

104. *Three-wire System.*—A three-wire system is one in which three conductors are maintained at different potentials, the conductor at a potential intermediate between the highest and lowest being common to all lamps or other consuming devices supplied from the system.

105. *Uninsulated Conductor.*—A conductor is said to be uninsulated when, although not metallically connected to earth, no provision is made by the interposition of a dielectric or otherwise for its insulation from earth.

APPENDIX.

The data for the resistances and weights of copper conductors are based on Matthiessen's standard as defined by the Committee on Copper Conductors in 1899, as follows:—

"Copper weighs 555 lbs. per cubic foot at 60° F. Its specific gravity = 8·912.

"Weight per mile in lbs. = 20,350 × area in square inches.

"Weight per yard in lbs. = 11·5625 × area in square inches.

"The temperature coefficient = 0·00238 per degree Fahr., or 0·00428 per degree Cent. = 0·06664 between 32° F. and 60° F.

"A lay of twenty times the pitch diameter is adopted as a standard, and the resistance in parallel of the wires is taken as the resistance of the cable.

"The resistance of *annealed* high conductivity commercial copper at 60° F. is :—

"Resistance per cubic inch = 0·00000066788 standard ohms.

"Resistance per cubic cm. = 0·00000169639 " "

"Resistance of 100 inches weighing 100 grains = 0·150158 " "

"The resistance of *hard-drawn* high conductivity commercial copper is :—

"Resistance per cubic inch = 0·000000681327 standard ohms.

"Resistance per cubic cm. = 0·00000173054 " "

"Resistance of 100 inches weighing 100 grains = 0·153181 " " "

The above formulæ give the standards, but a variation of 2 per cent in resistance or weight may be allowed for losses in manufacture.

TABLE XX.

Showing Maximum Currents, Thickness of Dielectric, and Insulation Resistance for Copper Conductors Insulated and Laid in Casing or Tubing.

1. *Gauge.* Number of wires and gauge in S.W.G. or inches.	2. *Section.* Nominal size of conductors in square inches.	3. *Rubber.* Minimum safe thickness of vulcanised rubber.	4. *Fibre.* Minimum safe thickness of dielectric for Class B.	5. *Lead.* Minimum safe thickness of lead for conductors (Column 4).	6. *Ampères.* Maximum ampères for rubber-covered wires exposed to high external temperatures.	7. *Ampères.* Maximum ampères allowable for rubber-covered wires. As in Col. 3.	8. *Volts drop.* Total length in yards lead and return for 1-volt drop in Column 6.	9. Ampères per square inch allowed in Column 7.	10. *Ampères.* Maximum allowable current for Column 4, Class B.	11. *Volts drop.* Total length in yards of lead and return for 1-volt drop (Col. 7 and Col. 10).	12. *Insulation.* Minimum insulation resistance for rubber.	13. *Insulation.* Minimum insulation resistance with thickness of dielectric of Column 4 for Class B.	14. Conductor resistance in B.O.T. standard ohms per 1000 yards.	15. Weight of copper in lbs. per 1000 yards.	16. Number of wires and gauge in S.W.G. or inches.
		Mils.	Mils.	Inch.					Ampères.		Mile-Megohms.	Mile-Megohms.			
1/18	·001810	35	35	0·030	3·2	4·2	24	2337	4·2	18	1200	300	13·28	20·93	1/18
3/22	·001825	36	35	0·030	3·3	4·3	23	2333	4·3	18	1200	270	13·18	21·62	3/22
1/17	·002463	36	40	0·030	4·0	5·4	25	2211	5·4	19	1200	270	9·762	28·48	1/17
3/20	·003016	38	40	0·030	4·7	6·4	27	2137	6·4	19	1200	250	7·972	35·75	3/20
1/16	·003217	36	40	0·030	4·9	6·8	27	2107	6·8	20	1200	250	7·478	37·2	1/16
1/15	·004072	37	50	0·030	5·9	8·2	29	2020	8·2	21	800	230	5·904	47·09	1/15
7/22	·004266	39	50	0·040	6·2	8·5	29	2002	8·5	21	800	220	5·636	50·36	7/22
1/14	·005027	38	60	0·040	7·0	9·8	30	1944	9·8	21	800	220	4·784	58·13	1/14
3/18	·005364	40	60	0·040	7·3	10·3	30	1922	10·3	22	800	200	4·482	63·52	3/18
7/20	·007052	41	70	0·050	9·0	13·0	32	1829	13·0	23	600	180	3·41	83·3	7/20
7/18	·01254	44	70	0·050	14·0	21·0	37	1649	21·0	25	600	160	1·918	148	7/18
19/20	·01912	48	70	0·060	20·0	29·0	40	1529	29·0	27	600	140	1·257	226·3	19/20
7/16	·02227	49	80	0·060	22·0	33·0	42	1487	33·0	28	600	140	1·080	263·1	7/16
19/18	·03399	54	80	0·060	31·0	47·0	46	1378	47·0	30	450	120	0·7074	402·2	19/18
7/14	·03483	54	80	0·060	31·0	48·0	46	1372	48·0	31	450	120	0·6903	411·1	7/14
7/·095″	·05	59	80	0·060	42·0	64·0	49	1286	64·0	32	450	120	·490	580	7/·095″
19/·058″	·05	59	80	0·060	42·0	64·0	49	1286	64·0	32	450	120	·488	591	19/·058″
19/16	·06039	62	80	0·060	48·0	75·0	52	1243	75·0	33	450	110	·3981	714·8	19/16
19/14	·09442	70	80	0·070	68·0	108·0	58	1147	108·0	36	300	100	·2547	1,117	19/14
19/·082″	·1	71	90	0·070	71·0	113·0	58	1135	113·0	36	300	100	·244	1,182	19/·082″
37/16	·1176	75	90	0·070	81·0	130·0	61	1102	130·0	38	300	90	·2045	1,393	37/16
19/·092″	·125	76	90	0·070	84·0	136·0	61	1090	136·0	38	300	90	·194	1,488	19/·092″
19/·101″	·15	81	90	0·080	96·0	158·0	65	1055	158·0	39	300	90	·160	1,781	19/·101″
37/·072″	·15	80	90	0·080	96·0	158·0	65	1055	158·0	39	300	90	·163	1,776	37/·072″
19/12	·1595	82	90	0·080	102·0	166·0	65	1041	166·0	41	300	90	·1507	1,888	19/12
37/14	·1838	86	90	0·080	114·0	187·0	67	1017	187·0	42	300	90	·1309	2,176	37/14
37/·082″	·2	87	90	0·080	121·0	200·0	66	1002	200·0	40	300	90	·125	2,303	37/·082″
61/15	·2455	95	100	0·090	142·0	237·0	72	965	237·0	42	300	80	·09795	2,907	61/15
37/·092″	·25	94	100	0·090	145·0	241·0	69	962	241·0	40	300	80	·0997	2,900	37/·092″
37/·101″	·3	101	100	0·090	166·0	279·0	73	931	279·0	43	300	80	·0827	3,494	37/·101″
61/14	·3029	102	100	0·090	168·0	282·0	75	930	282·0	45	300	80	·07937	3,589	61/14
37/12	·3105	103	100	0·090	170·0	287·0	76	925	287·0	45	300	80	·07744	3,678	37/12
37/·110″	·35	107	100	0·090	187·0	317·0	77	906	317·0	45	300	80	·0697	4,145	37/·110″
37/·118″	·4	113	100	0·100	208·0	354·0	79	883	354·0	47	300	80	·0606	4,772	37/·118″
61/·092″	·4	113	100	0·100	208·0	354·0	80	883	354·0	47	300	80	·0605	4,781	61/·092″
61/·101″	·5	121	100	0·100	248·0	425·0	80	850	425·0	47	300	80	·0502	5,762	61/·101″
61/12	·5120	124	100	0·100	252·0	433·0	84	846	433·0	49	300	80	·04697	6,065	61/12
61/·110″	·6	129	110	0·110	282·0	493·0	84	822	493·0	48	300	80	·0423	6,836	61/·110″
91/·092″	·6	131	110	0·110	282·0	493·0	88	822	493·0	50	300	80	·0405	7,134	91/·092″
91/·098″	·7	138	110	0·110	320·0	560·0	88	799	560·0	50	300	70	·0357	8,094	91/·098″
91/·101″	·75	141	110	0·110	340·0	592·0	88	790	592·0	50	300	70	·0336	8,597	91/·101″
91/·104″	·8	144	120	0·120	352·0	624·0	90	781	624·0	51	300	70	·0317	9,115	91/·104″
91/·110″	·9	151	120	0·120	390·0	688·0	91	764	688·0	51	300	70	·0283	10,200	91/·110″
91/11	·9504	158	120	0·120	406·0	719·0	97	757	719·0	55	300	70	·02530	11,256	91/11
91/·118″	1·0	160	130	0·120	424·0	750·0	96	750	750·0	54	300	70	·0246	11,740	91/·118″
127/·101″	1·0	161	130	0·120	424·0	750·0	99	750	750·0	56	300	70	·0239	11,910	127/·101″

The sizes of the conductors in col. 2, which are expressed in exact decimal parts of a square inch, such as ·05, ·3, ·5, etc., are not the absolutely correct figures which would be found by calculation, but are the sizes adopted by the Cable Makers' Association as the most suitable for manufacture in order to avoid the unnecessary expense involved in supplying a multiplicity of odd sizes of wire.

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APPENDIX III.

EXAMINATIONS IN SCIENCE, SOUTH KENSINGTON.
SUBJECT III.—BUILDING CONSTRUCTION.

General Instructions (1903).

If the rules are not attended to, the paper will be cancelled.

Immediately before the Examination commences, the following
Regulations *are* to be read to the Candidates.

Before commencing your work, you are required to fill up the numbered slip which is attached to the blank examination paper.

You may not have with you any books, notes,[1] or scribbling paper.

You are not allowed to write or make any marks upon your paper of questions, or to take it away before the close of the examination.

You must not, under any circumstances whatever, speak to or communicate with one another, and no explanation of the subject of examination may be asked or given.

You must remain seated until your papers have been collected, and then quietly leave the examination room. None of you will be permitted to leave before the expiration of one hour from the commencement of the examination, and no one can be re-admitted after having once left the room.

Your papers, unless previously given up, will all be collected at ——.

If any of you break any of these rules, or use any unfair means, you will be expelled, and your paper cancelled.

Before commencing your work, you must carefully read the following instructions:—

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a

[1] In certain practical examinations candidates were allowed the use of books, notes, etc.—*see* special instructions preceding the papers of questions in those subjects.

larger number of marks than an incomplete or inexact answer to a more difficult one.

Questions marked (*) have accompanying diagrams.

NOTE.—*A candidate in any subject who applied for examination in the Elementary Stage was required to confine himself to that stage. A candidate who had not applied to take the Elementary Stage was allowed to take the Advanced Stage, or, if eligible, Honours, Part I. or II., but was required to confine himself to one of them.*

1902.

Advanced Stage.

You are permitted to answer only *six* questions.

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21. Explain why the sand for mortar should be clean sharp sand free from clay. What is a hydraulic lime, and in what respects does it differ from rich or fat lime? Portland cement is made from lime and clay; explain the difference beween Portland cement mortar and common lime mortar to which clay is added. (24.)

22. If it is an advantage to have wide joints for brickwork, built with Portland cement mortar, what change in the dimensions of the bricks is desirable for such work? What tests should be applied to a particular make of bricks, proposed to be used in important exposed work and built with cement mortar? What are fire-bricks, and how do they differ from common bricks? (24.)

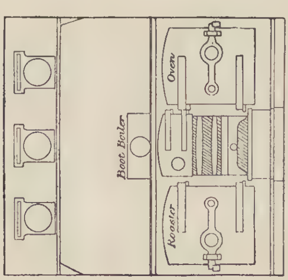
23. Take 9 bushels of sand, and 3 bushels of Portland cement, and make it into mortar; how many bushels of mortar (approximately) will you have? If upright joints are $\frac{1}{2}''$ thick, and the beds $\frac{7}{8}''$ thick (allowing for the frog), how many courses of a two-brick wall 12 bricks long will this quantity build? The dimensions of bricks are $9'' \times 4\frac{1}{4}'' \times 3''$. Will you use more mortar per cubic yard of brickwork in a two-brick wall than in a one-brick wall, and if so how much more? (24.)

*24. Explain and illustrate by sketches how you would set the kitchen range shown? Show the flues; show by a diagram the connections between the boot boiler and the hot-water cocks in scullery, bathroom, etc. Why is a safety-valve needed? Show where it may be placed. (24.)

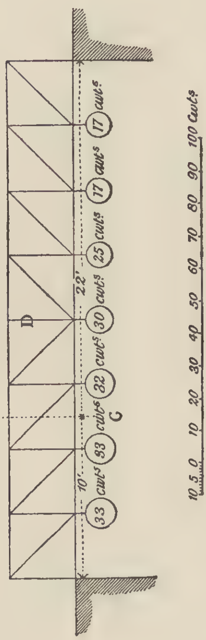
25. Sketch neatly to the scale of $\frac{1}{12}$, showing the mortar joints with double lines, the elevation of about $4' \times 4'$ of snecked rubble wall; give also the top of the sample in plan. How many bushels of sand and of lime, and what weight of "stock" (stone), approximately, is needed per cubic yard for this masonry,—the wall is 18″ thick? (28.)

26. How would you prepare 6 bushels of plasterer's coarse stuff (21 bushels in a cubic yard)? Give the quantities of sand, lime, and hair. How many square yards of lathed work will this quantity cover—two-coat work? Describe "scouring" and "setting." How is gray setting stuff prepared? What is gauged putty set, and for what is it used? (28.)

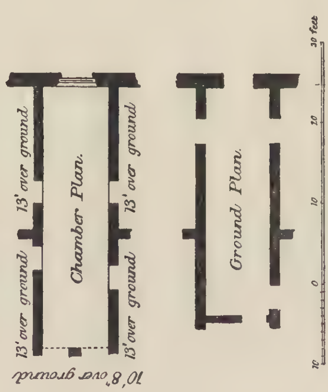
24


Boot Boiler
Oven
Roaster

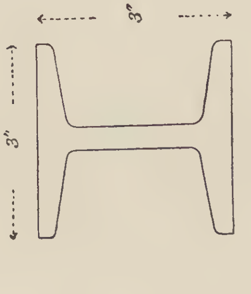
31 — 32


B
C
D
10'
22'
33 cwts
33 cwts
32 cwts
30 cwts
25 cwts
17 cwts
17 cwts
10 5 0 10 20 30 40 50 60 70 80 90 100 cwts

51


13' over ground
13' over ground
13' over ground
13' over ground
10' 8" over ground
Chamber Plan.
Ground Plan.
10 0 10 20 30 feet

46


3"
3"

27. Describe the mixing of paint from its common commercial state—ground in oil. Describe the complete painting of a new white-deal inside door; it is to be finished a light drab colour. How would you test, for adulteration, a sample of white lead which has been ground in oil? (29.)

28. You have to slate a house of which the eave is 23′ from the ground. Describe how you will proceed with the work: dress the slates, scaffold, provide battens and nails. How will you dress for mitre valleys and hips? Sketch a slate (24″ × 12″) holed and dressed. At what parts of a roof does waste occur? How many square inches of complete roof may one slate (24″ × 12″ and 4″ lap) be supposed to cover? (33.)

29. Draw carefully to the scale of $\frac{1}{12}$ the half-outside elevation of a double-leaved hall or porch door. The door opening is 7′ 3″ × 4′: the door, each leaf in three panels; top panels raised centres, bolection moulded; lowest panels flush and beaded. Show top light and sidelights. The opening—soffit of reveal to top of door sill 9′; from reveal to reveal 7′ 6″. Give a vertical section from 6″ above soffit to door step, showing door frame and sash of top light, and passing through panels of door, showing weather board and door sill. (33.)

30. Of the two wires to an electric bell-push one is found to be more liable to be injured by corrosion than the other. Assuming that these two wires go directly to the battery, one of them is attached to a zinc rod and the other to what projects above a "porous pot"; which wire is most liable to corrosion? What special care would you give to the corroding wire to prevent its corrosion? Show by a diagram how you would connect a number of pushes with the bell, indicator, and battery, so that there will be a minimum quantity of corroding wire. (33.)

*31. Skeleton drawing of a bridge truss loaded as shown; transfer it to your paper. Draw the stress diagram to the scale shown; mark on the truss the amounts of the stresses in cwts., showing compressions by the sign + and tensions by the sign −. (36.)

*32. In the truss of the previous question loaded as shown, what is the bending moment at *BC* and by what stresses is it resisted? Of what use is the member *D*? (36.)

Honours—Part I.

You may not answer more than six questions, of which at least one must be selected from each of the first two divisions and two from the last.

Drawings, sketches, and answers may be on the squared paper which is attached to the drawing paper. Additional foolscap may be obtained from the Superintendents of the examination.

Division I.

41. Describe the complete operation of brickmaking. Candidates who have experience of the actual operation should answer from their direct observation, as far as possible. (45.)

*42. A portion of the trunk of an oak. Draw a cross section (the clean freshly sawn and smoothed end of the trunk polished if necessary). Show such markings as you think deserve notice and description. Suppose that the tree is sawn longitudinally on the line AB and that the sawn face is polished, sketch such markings as will appear (what a house painter imitates in graining). Show the markings when the cut is on the line CD. Identify the various portions of structure which present different appearances in the three sections. Show how you would take a plank that would be least affected in its breadth by shrinkage in seasoning. (45.)

43. Describe the quarrying of a good building stone. Give the geological formation to which it belongs, or name the quarry and give the general character of the stone. Sketch and describe the tools used. If the candidate has had opportunity to see actual quarrying he should endeavour to describe what he has seen. (45.)

Division II.

*44. Determine graphically the stresses in the roof truss shown. Mark the amount of the stress in each member, on the member, and show compression by the sign + and tension by the sign −. (51.)

45. A brick wall is 10′ high; it is $13\frac{3}{4}''$ thick; it may be taken as resting, without adhesion, on a horizontal bed at the ground level, and on which it bears uniformly. Assuming its weight to be 120 lbs. per cubic foot, and that its safe load (for crushing) is 8 tons per square foot, what wind pressure per square foot will it safely bear? Sketch a vertical cross section and show the centre of pressure on the bed which will accord with the assumption of a maximum pressure of 8 tons per square foot. (51.)

*46. What is the weight per foot run of the mild steel joist shown (approximately)? The formula $D=\frac{5WL^3}{384EI}$ gives the deflection of a beam under a load. For this formula to apply, in what way is the beam supported and how is it loaded? What do the letters E and I represent? (45.)

Division III.

47. A railway is carried over a common road on a masonry arch; the centre line of the railway makes an angle of 60° with the centre line of the road; the width of the road is 24′; the arch is segmental (at right angles to the centre line of the road) having a rise of 9′. Draw the half elevation of one face, showing the obtuse angle of an abutment, and showing the joints in the half ring. In what respects do these ring joints differ from the ring joints of a direct elliptical arch when they are drawn as normals to the intrados curve? Show how you draw normals to an ellipse. Describe what you understand by a coursing helix in the sheeting of a skew arch. (51.)

*48 Design the truss shown. Sketch sections of its parts and the different joints to the scale of $\frac{1}{6}$. What is the weight of the truss? (51.)

49. A hall in a girls' school is 64′ × 24′; it is divided into three equal class-rooms by movable partitions. The floor above is partitioned

into music rooms: it is important that no sound shall pass through the floor and ceiling. The floor and ceiling are carried on rolled joists, which lie across the 24′ span, and these are managed so as to show below the ceiling as little as possible. No timber enters any wall. Give such sketches and explanations as would fairly direct an intelligent foreman to have this floor and ceiling properly and sufficiently constructed. (51.)

*50. The drawing shows the outline of portion of a building and the direction of a public sewer, *F*, near it. Show by neat sketches how you would propose to execute drainage to serve the wastes shown. *A*, water-closet soil pipe; *B*, the bath waste; *C*, the down-spouting; *D*, scullery waste; *E*, pantry waste. Give such short explanations as you think are needed. State shortly what you think is the whole duty of house drains. (51.)

*51. Design staircase and landings in the hall shown so as to give access to the several doors. The staircase is of wood—oak balusters and handrail, red pine steps, strings, etc., returned nosings, bracketed, etc. Illustrate your explanation by neat sketches. (51.)

52. A drawing-room, 30′ × 25′; ceiling, 14′ over floor, is to be plastered. The two 25′ walls and one 30′ wall are outside walls. Give full and minute instructions for the plastering of the room. Sketch profile of the cornice and any other mouldings you propose to use. There are two doors, one large double-leaved door and one ordinary sized door (in a good house); there are four windows. The combined area of doors, windows, and fireplace over the level of skirting grounds is 360 square feet. Skirting grounds 1′ over floor. Take quantities of the work and estimate the cost. (51.)

Honours—Part II.

NOTE.—*No Candidate will be credited with a success in Part II. of Honours who has not obtained a previous success in Honours of the same subject.*

You may not answer more than five questions, one of which, and not more, must be selected from each of the first two divisions.

Those Candidates who answer this paper well, will be admitted to a practical examination at South Kensington. Candidates admissible to that examination will be so informed in due course.

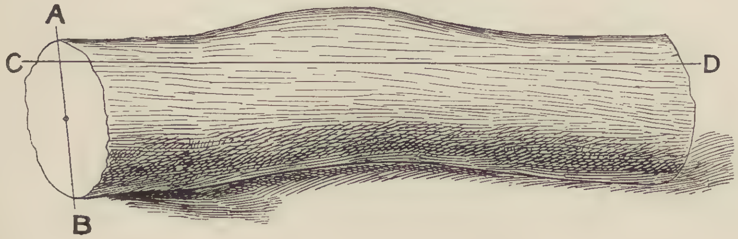
The sketches for 61 and 62 should not be on squared paper, they should be on foolscap. The outlines should be firm and the work should be very neatly done and the proportions reasonably accurate.

The other sketches should as far as possible be on the squared paper attached to the drawing paper; they should first be done in pencil, and then neatly outlined with the ordinary writing pen and ink to make them clear and distinct.

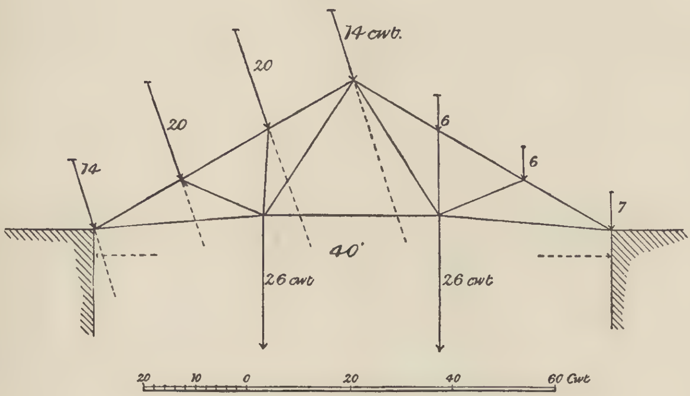
Foolscap paper may be obtained on application to the Superintendents of the examination. Written answers should be in ink, and must adjoin the sketches to which they refer.

1902.

42



44 ~ 48



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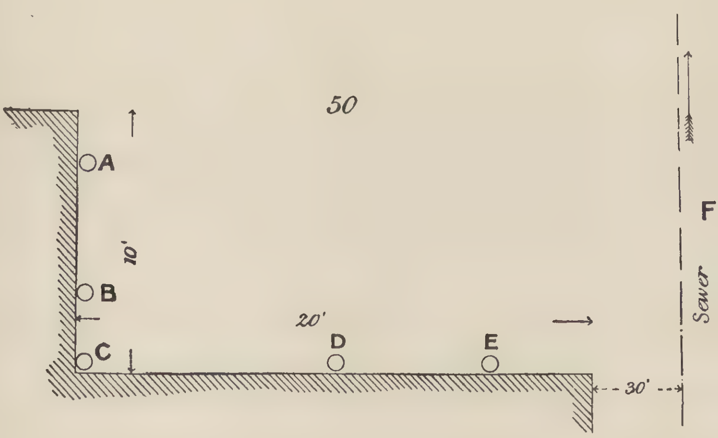


DIVISION I.

61. Answer only *one* of the following, (*a*) or (*b*) :—

(*a*) What are the Elgin Marbles? Where are they? To what building did they mainly belong? Who were the architects of the building? And who was the sculptor who had supervision and control of the sculpture? or (80.)

(*b*) Sketch a Greek Ionic Capital (credit will not be given for the sketch if it is carelessly done). (80.)

62. Answer only *one* of the following, (*a*) or (*b*) :—

(*a*) Plan of Westminster Abbey. In what style is the greater part of the building? Transfer the plan to your paper. Indicate where you would take a friend to show him (*a*) Saxon and Norman work, (*b*) late Perpendicular work. What important portion was built in the beginning of the eighteenth century, and what style is imitated in this work? (80.)

(*b*) What are pylons? Sketch neatly the elevation of a building showing pylons. (80.)

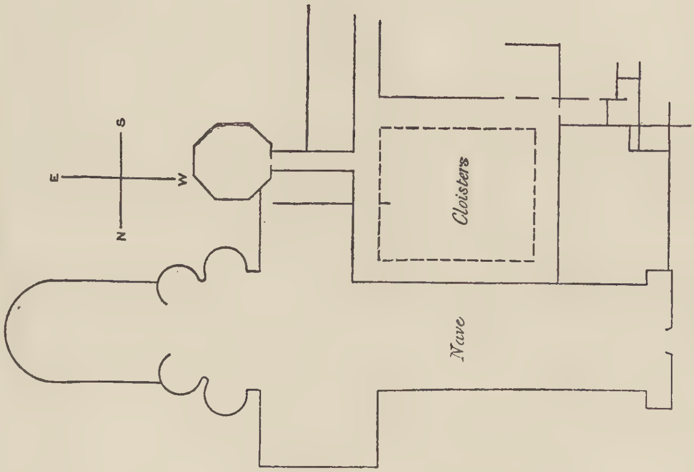
DIVISION II.

63. Write full instructions for a specification for a bridge of a single arch to carry a 20′ roadway over a stream (the instructions should refer to the general conditions of the contract as well as to the actual works, but they are to be no more detailed than is necessary to enable an assistant to draw up the full specification). The centre line of the stream makes an angle of 60° with that of the road: there is a good rock foundation at the level of the bed of the stream: abutments 6′ high (to springing from rocky bed): span, at right angles to centre line of stream, 20′: arch segmental on cross section, at right angles to the centre line of the stream, having a rise of 8 feet: banks of stream 6′ over bed, 30′ from bank to bank. The road and fences are carried on filling which slopes 1 to 1 to level top of river banks. The general work is to be masonry built with Portland cement mortar, showing squared uncoursed wide jointed rubble in faces. Copings to be thorough stones, not laid on a prepared continuous bed, but rising from the uncoursed masonry, chisel drafted along top corners and smooth dressed on top. The sheeting is to be of blue bricks in cement mortar. Make such sketches as will sufficiently direct your office assistant to make accurate drawings. (80.)

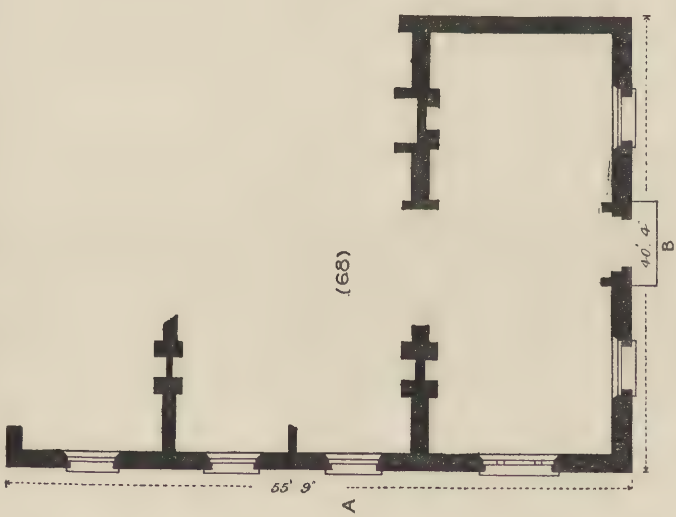
64. The walls for a stable have been built, and a hayloft has been constructed over the stable; this floor has been pugged. Openings have been formed for door (7′ × 4′) and two windows (each 5′ × 4′) in one side wall (long dimension); they are placed symmetrically with reference to the outside of the wall. The space within the walls is 28′ × 18′, and the lower edges of the joists are 12′ over the level of the door sill. Write full instructions for a specification for: (*a*) the windows and door, (*b*) floor, and drainage, to be carried to an outfall through the wall opposite to the door, (*c*) plastering and such finishing of walls as you think advisable, (*d*) stall divisions and other fittings, (*e*) water supply, hay supply, ventilation, vermin prevention. Draw

1902.

(62)



(68)



such neat dimensioned sketches as will enable a draughtsman to make accurate drawings. (80.)

DIVISION III.

65. Take accurate quantities for the bridge of Question 63; price them and write out a detailed estimate. (80.)

66. You are commissioned to prepare a design with complete drawings and specification for a school to cost £8000, to advertise and arrange for tenders, and to supervise and control the work as architect and agent for the proprietors. Write out in detail, and as nearly as you can in order and sequence, the steps by which you will perform this work. You are to treat of: (*a*) design, (*b*) drawings and copies, (*c*) specification and copies, (*d*) quantities and copies, (*e*) advertisement for tenders and selection of a contractor, (*f*) agreement, (*g*) appointment and control of clerk of works, (*h*) portions of the work such as steam heating, laundry, electric plant, etc., as to which you think consultation with specialists necessary. (80.)

67. Describe: (*a*) office modes of producing multiple copies of drawings, (*b*) manifolding typewriting, (*c*) manifolding manuscript, (*d*) storing drawings so as to be carefully kept and easy of access, (*e*) arranging files of correspondence for easy reference in connection with particular works, (*f*) record of certificates, (*g*) record of expenses. (80.)

*68. Draw to the scale of $\frac{1}{96}$ elevations of fronts *A* and *B* of the thatched cottage shown. Specify carefully with minute detail: (*a*) the operation of thatching, (*b*) forming reveals to door and windows, (*c*) roughcasting of walls, (*d*) how the surface of the ground is to be finished along the walls. (80.)

69. Design a fireplace, grate, mantel, and overmantel and cornice in a drawing-room. Height of ceiling from floor 13′. Sketch so much of each proposed separate detail as may be necessary to show accurately what is intended at every part of the work. These sketches should be very neatly done. (80.)

70. You have to cover a rectangular space and the walls enclosing it with a wagon roof of sheeting felted and the felt tarred. Inside dimensions 80′ × 30′, walls 18″ thick. Write down accurate detailed instructions for: (*a*) making and bracing the ribs—with sketches, (*b*) spacing, and bearing on walls, (*c*) sheeting, felting, tarring, (*d*) eaves gutters, and spouting, and any details that may occur to you. Make the roof thoroughly strong and secure. Take off and make up the quantities accurately and draw up a detailed estimate for the work. (80.)

Honours—Part II.

PRACTICAL EXAMINATION AT SOUTH KENSINGTON.

Time allowed, seven hours.

Design a shop with dwelling over. The available site is a rectangle having a frontage to the street of 30′ and a depth from front to rear of 50′. The shop and the hall entrance to the dwelling will occupy the

whole of the ground floor. There can be no windows or doors in walls of ground floor except in the street frontage. At first-floor level you are free, for a depth of 28′ from the front, to build upwards as high as you please, but you cannot have windows in the party walls. You may have windows above the ground floor in any back wall not more than 28′ from the frontage line and you may put roof lights over the back part of the shop within the limits of the site. Dwelling :—Entrance-hall and stairs, two sitting-rooms, four bedrooms, kitchen, scullery, pantry, store for groceries, etc., larder, servant's bedroom, linen room, W.C., and bathroom. There is a common passage along outside the rear boundary 10′ wide.

Give such plans and sections as will fully explain your design. Give the front elevation in skeleton but finish parts, sufficient to show your treatment of the whole front. Draw upper floor plan inked in and write names of apartments and dimensions in ink. General work in pencil, outline filled in, in water-colour (just enough to make the drawings clear).

1903.

Advanced Stage.

You may not answer more than *six* questions.

The drawings in answer to Questions 24, 27 (any drawing the candidate may think useful for 29), and 30 should be on the drawing paper ; they may be in pencil. Written answers on squared paper (and foolscap) should be in ink. Additional foolscap may be obtained from the Superintendents of the examination.

21. What is quicklime, and how is it produced ? Use such terms as you think would be intelligible to a workman, familiar with the handling of lime and plaster of Paris, and describe : (*a*) what happens when water is applied to quicklime ; (*b*) what happens when plaster of Paris is mixed with water—to be used for casts : giving the best rational explanation you can of the actions. (24.)

22. You have a special kind of timber from which to take flooring joists. The formula

$$\triangle = k\frac{wL^4}{bd^3}$$

expresses a law, where $\triangle$ stands for the drop or deflection at the centre, w the load per unit of length, L the length between the supports or bearings, b the breadth or thickness, d the depth. Describe an experiment (using a piece of the timber and making use of bricks for load, etc.), by which you can determine k. (24.)

(*See* note to Question 24.)

23. Assuming that you have made the experiment of the previous question and that you have found k to be ·000000084 (the units being :—foot and hundredweight) ; what is the stress per unit of cross-

sectional area on the outer fibres at the cross section of greatest bending moment:

$L = 20'$, $b = \frac{1}{6}'$, $\triangle = \cdot 05'$, $w = 1 \cdot 25$ cwt.? (36.)

(*See* note to Question 24.)

*24. Draw the stress diagram for the roof truss loaded as shown. (29.)

(*Note.*—A Candidate can obtain marks for not more than two of the three questions Nos. 22, 23, and 24.)

25. Answer only one of the following, (*a*) or (*b*):—

(*a*) Bricks ($9'' \times 4\frac{1}{4}'' \times 3''$) cost 35s. a thousand; Portland cement costs 3s. 6d. a bushel; sand costs $2\frac{1}{2}$d. a bushel (all as delivered on the works). What is the cost for these materials for a cubic yard of two-brick wall (mortar, 1 of cement to 3 of sand, joints to show $\frac{1}{2}''$ thick)? (21 bushels in a cubic yard.) (33.)

(*b*) Bricklayers' wages are 1s. an hour, attendants' wages 6d. an hour; for plain brick walling, 16 to 30 feet over ground, give a reasonable proportion between cost for bricklaying and cost for attendance. Including both items, what is a fair cost per cubic yard for workmanship? What other items of expenditure should be charged to the brickwork? Give reasons for your proportion and estimate. (33.)

26. In towns where ashlar masonry is common the lintels to window and door openings, though of excellent stone, are seen to be in very many cases broken across; explain the cause of this. How might this fracture of lintels be prevented? (24.)

27. Draw (*a*) the elevation, (*b*) a vertical cross section at the centre, and (*c*) a half horizontal cross section (just over the grate) of a good register-grate fireplace, to the scale of $\frac{1}{8}$. How is the fireblock back to be renewed? How is the chimney to be swept and the soot cleared away. (33.)

*28. A cornice of the cross section shown is to be formed round the ceiling of a room: describe the complete operations (omit the making of modillions and their attachment, also the finishing of the soffit): describe the materials used: describe moulds, screeds, rules, and tools used, and modes of using them. How are the dentils made and attached? Describe the working of a mitre. (36.)

29. A right circular cone roof, over a lantern, is $8'$ in diameter at the eave, it is $3'$ high (from base at eave to vertex), it is to be covered with copper plates in the manner of slating, they are trimmed and bent to fit on. The margin is $6''$, the lap is $3''$; the apex is finished with a conical cap of sheet copper, $8''$ diameter at the base; the sheet copper weighs 3 lbs. per superficial foot; omitting nails, what is the total weight of copper on the roof? (33.)

30. Draw carefully to the scale of $\frac{1}{8}$ the horizontal cross section of a fully-trimmed window, through one jamb and reveal. The wall is of stone, ashlar face; reveal $6''$ deep; wall $2'$ thick, battened (or stoothed). Show jamb-lining, three-faced architrave, folding shutters (window about $4'$ wide), ground, lathing, and plaster. Sketch to the scale of $\frac{1}{6}$, cross section through sash bottom rail, oak sill, and stone sill. If you adopt a water-bar explain how you prevent water passing inwards at the ends of the oak sill. (28.)

31. Answer only one of the following, (*a*) or (*b*) :—
    (*a*) Sheet lead which is repeatedly treated to sudden dashes of warm (or hot) water wrinkles permanently in a remarkable manner (seen when a scullery or pantry sink is, as is occasionally done, lined with sheet lead): explain this. (24.)
    (*b*) Sketch neatly and clearly a longitudinal section of a good screw-down bib-cock. (24.)

*32. Trace neatly, in ink, the drawing shown, also the writing and figures. (The Indian ink should be sufficiently thick to give opaque lines suitable for photographic printing ; the lines should be well defined, uniform in breadth, having firm, unbroken edges; they should neither stop short of nor go beyond the proper points.) (28.)

Honours—Part I.

You may not answer more than six questions, of which at least one must be selected from each of the first two divisions and two from the last. The tracing must be attempted.

Sketches and answers may be on the squared paper which is attached to the drawing paper. Additional foolscap may be obtained from the Superintendents of the examination.

The *tracing* should be *drawn* on the tracing paper attached to the drawing paper.

The drawings, in answer to Questions 44 and 50, should be on the drawing paper ; they may be in pencil.

Division I.

41. (*a*) Describe a lime-kiln—illustrate with sketches. Describe the preparation of limestone for burning. (*b*) Given—Ca 40, O 16, C 12 ; what weight of lime should result from a charge of 4 tons of limestone? The weight of limestone is made up of 3·424 tons of $CaCO_3$ + ·4 ton of a substance not altered in weight by the burning, + ·176 ton of water which is driven off. (*c*) How many cwt. of coals (approximately) are required to burn 4 tons of limestone to lime? (51.)

42. Describe exactly the manufacture of lead pipes for plumbers' work. Illustrate your description with sketches. (45.)

43. Describe carefully the preparation of plaster of Paris. In what respects does plaster of Paris differ from the gypsum from which it is made? (45.)

Division II.

*44. It is assumed that the girder shown may be separated into two determinate girders, placed side by side, and the load also divided and placed equally on the two girders. When thus loaded and stressed the two girders may be recombined without alteration in the stresses. On this supposition, find graphically the stresses in the members of the girder loaded as shown. (Full marks will be given for an

accurate continuous diagram which will include all the joints between A and B.) (51.)

45. The reservoir (for distribution) of the waterworks of a small town is a circular cylinder, 30 feet high and 20 feet in diameter. When the cylinder is full of water, what is the tensional stress in a ring of the cylinder 1 foot wide (or deep), whose centre line is at the height of 1 foot 6 inches from the bottom? What should be the thickness of iron plate to *safely* sustain this stress? (51.)

*46. A mild steel joist, of the cross section shown, rests horizontally on two supports, one at each end, having its web vertical; it is 40 feet long:—

(*a*) Given

$$\triangle = \frac{5}{384} \frac{WL^3}{EI}, \ E = 30{,}000{,}000 \text{ (lb.-in.)},$$

$$I = \frac{bd^3 - b_1 d_1^3}{12},$$

find $\triangle$ in inches. (Rounded angles taken as not rounded; take the average thickness of flanges.)

(*b*) What is the *maximum* stress in lbs. per square inch upon the steel at the cross section of greatest bending moment? (51.)

Division III.

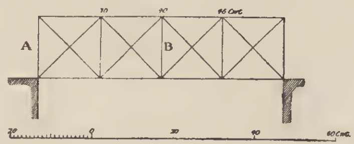
*47. The drawing shows a vertical section, through a diameter, of a circular concrete and masonry reservoir; the flat cover is supported upon cast-iron pillars, 6 inches in diameter, metal $\frac{3}{4}$ inch thick; square flanges on their ends, 12 inches by 12 inches, $\frac{7}{8}$ inch thick (the pillars are not shown on the drawing, they are 34 in number). Find accurately (*a*) the quantity of masonry and concrete combined; (*b*) the quantity of water in gallons that the reservoir will hold when the water surface is within six inches of the roof; (*c*) the weight of iron in the pillars; (*d*) the quantity of surface to be floated and trowelled smooth; (*e*) draw up an estimate of the cost of this resevoir (omit standpipe, overflow, and washout; but include manhole and foot irons). (51.)

48. Sketch to the scale of about $\frac{1}{8}$ a vertical section to show the parts of a first-class wash-down water-closet. Show the connection with the soil-pipe: show the flushing tank and explain its parts and mechanism: show particularly the connections of the porcelain with the metal piping. (51.)

49. Give careful instructions; give dimensions; make sketches of parts; specify particularly the materials; for a good ordinary pattern house-painters' ladder 30 feet long. How much should it cost? (45.)

*50. The drawings show the ground floor, and the first and second floors of a building and the doors opening into a central well; there is a third floor having 3 doors exactly over the three doors marked 25′ on the second-floor plan: design stairs and landings for these floors: the height of the third floor is 40 feet; winders are not allowed: it will be sufficient to show the risers of bottom steps and top steps at landings, etc., and to give the number of intermediate risers:

(44)



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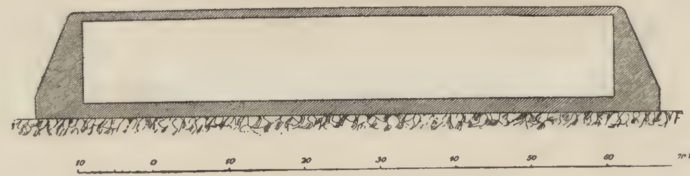
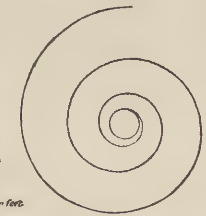


Scale, (47) and (50)

(52)

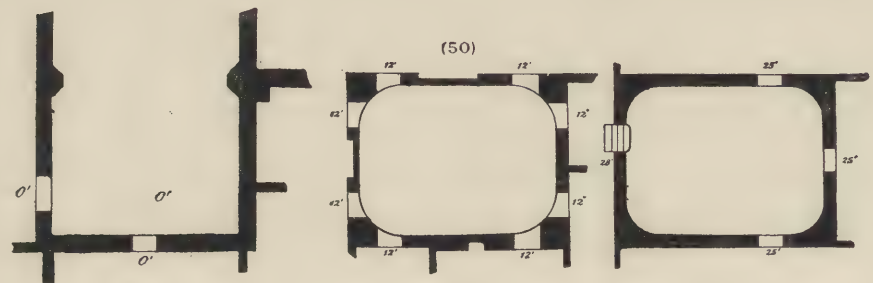


Ionic Volute

(46)

One sixth of full dim^s

(50)



Ground

First Floor

Second Floor

landings should be marked distinctively with two diagonal lines. The heights, over ground, of the different floors are marked on the plans.—Ground floor 0′, first floor 12′, second floor 25′ and 28′ (the risers are shown from the 25′ level to 28′ level). (51.)

51. (*a*) Sketch to the scale of $\frac{1}{8}$ the head and point of a 12″ × 12″ timber pile prepared for driving. (*b*) What do you know of the pressure between the base of the monkey and the head of the pile after impact? (*c*) If a monkey weighing 8 cwt. falls 7 feet to the head of a pile and drives the pile 1 foot, what is the effective average pressure on the head of the pile during its motion? (*d*) If the pile is driven only a very short distance (or is not noticeably moved), can you estimate the force or pressure? (*e*) In general terms, compare the effect of the stroke of a monkey of, say 4 cwt., falling 14 feet, with that of the monkey and fall given above. (51.)

*52. Trace, in ink, the Ionic volute curve shown, and the words "Ionic volute." (This curve is a series of quadrants of circles: it is important—for full marks—that the line shall be uniform and that no points of junction shall show.) (45.)

Honours—Part II.

NOTE.—*No Candidate will be credited with a success in Part II.—Honours who has not obtained a previous success in Honours.*

You may not answer more than five questions, one of which, and not more, must be selected from each of the first two divisions. You must also attempt the tracing.

The sketches, Questions 61 and 62, should be drawn on the drawing paper—not on the squared paper: they may be first sketched in pencil, but they are expected to be neatly finished, as pen sketches, in Indian ink.

The other sketches should be clear and effective. Candidates may (in this stage) draw them either on the squared paper or on the drawing paper. Writing on squared paper and on foolscap should be in ink.

DIVISION I.

61. Answer one only of the following, (*a*), (*b*), (*c*), or (*d*):—
    - (*a*) Draw, to fill a space $2\frac{1}{2}$″ deep and 5″ long, the Greek double guilloche ornament. (80.)
    - (*b*) Sketch, to fill a band $2\frac{1}{2}$″ deep, the complete honeysuckle and lotus, or papyrus and lotus, Greek ornament. (80.)
    - (*c*) Draw faintly in pencil 14 parallel straight lines $\frac{3}{16}$″ apart; on these, making use of them, work a Greek fret. (80.)
    - (*d*) What is a *Choragic* monument? Describe the Choragic Monument of Lysicrates. Sketch the termination of a flute (at its top). (80.)

62. Answer one only of the following, (*a*), (*b*), or (*c*):—
    - (*a.*) Sketch for each of the "styles":—Norman, Early English, Decorated, and Perpendicular,—at least one characteristic moulding ornament. (80.)

(*b*) Sketch for each of the "styles":—Norman, Early English, Decorated, and Perpendicular,—the top of a buttress. (80.)

(*c*) Sketch a Moorish Capital (Alhambra) with fairly elaborate ornament. (80.)

DIVISION II.

*63. The drawing shows the plan and the front elevation of a cottage which has been built for the accommodation of a clergyman. Write down full instructions which would be sufficient to guide an assistant to write a complete specification for the work, to be executed by contract.

Instruct him as to *detail* drawings. Note for his guidance any small omissions on the drawing. (80.)

(*See* note, Question 65.)

64. Make such sketches as will enable an assistant to make complete drawings for a switch and signal cabin at a village railway station. Write full instructions from which he can write a specification for the work, which is to be done by contract (omit levers and electrical arrangements). (80.)

DIVISION III.

*65. Take accurate quantities of the masonry and brickwork of Question 63. Bring them into bill and estimate the cost in detail. (Candidates, who prefer to do so, may assume the outside walls to be of brickwork 9″ thick, keeping the outer faces as shown: this note also applies to Question 63.) (80.)

66. Take accurate quantities for the signal and switch cabin, Question 64, bring them into bill and estimate the cost in detail. (Omit levers and electrical arrangements.) (80.)

67. You have to carry a railway through a hill; the surface of the ground is 40 feet above the "formation" surface of the railway (that is the surface which is prepared to receive the ballast to sustain the sleepers); the total breadth of the formation and drains is 25′; the slopes in open cutting would be secure at 1 to 1; the ground is easy to get and to fill: you have to decide whether;—(*a*) you will have an open cutting with slopes the whole way down to the formation; (*b*) you will have an open cutting with revetment walls; (*c*) you will excavate a tunnel and line it with brickwork: describe in what way you will seek to come to a sound conclusion (the question is one of cost only). Sketch half cross sections of (*a*) open cutting the full depth; (*b*) open cutting with revetment walls 10 feet high; (*c*) the tunnel: stone costs 3*s.* a ton, bricks 35*s.* a thousand, Portland cement 40*s.* a ton, sand $2\frac{1}{2}d.$ a bushel. Find the cost of a yard forward on each assumption. (80.)

68. Coating iron with zinc in the manner called "galvanising" protects the iron from rusting at scratches which expose the iron surface, and at small bare areas wider than scratches make; coating iron with tin does not protect the iron in the same way: explain this. (80.)

69. Write instructions for a clerk of works (whom you have appointed to

supervise the building of a large house; the work is being done by contract); they should regulate his dealing with doubtful materials and workmanship, his reports to you, his attendance on the work, etc., etc. (80.)

*70. Trace, in ink, the plan of the cottage, also the dimensions and the writing—on the plan. (The lines should be opaque so as to give good prints.) (80.)

Honours—Part II.

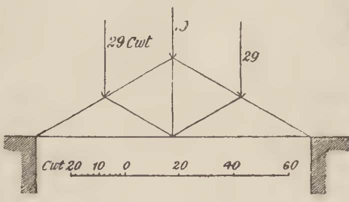
PRACTICAL EXAMINATION AT SOUTH KENSINGTON.

Time allowed, seven hours.

Design a village elementary school, of one story, for 60 male pupils. The site is a rectangular plot having 100 feet frontage to a public road, and it is 200 feet in depth. In the road there is a public sewer and a water supply main.

Give a skeleton drawing, to a small scale, showing how you place the school; the road runs east and west and the plot is on the north side of the road. You have to build a boundary wall 6 feet high and to provide for entrance and exit. Give such plans, elevations, and sections, to the scale of $\frac{1}{96}$ as you think sufficient for the letting of the work to be executed by contract. (The soil is compact homogeneous clay.) Candidates should make a list of the items of accommodation which they think necessary; they should provide for this accommodation in the most substantial, efficient, and economical ways. The elevations should be appropriate and in good taste. It will be sufficient to draw, in detail, one feature (as a window, etc.) where there are several identically the same. The site may be taken as level. *Large scale* detail drawings are not expected.

(24)



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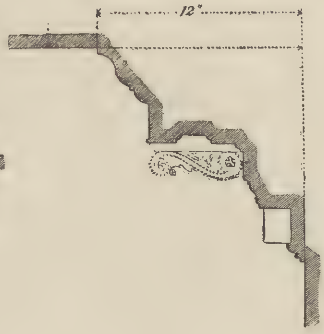
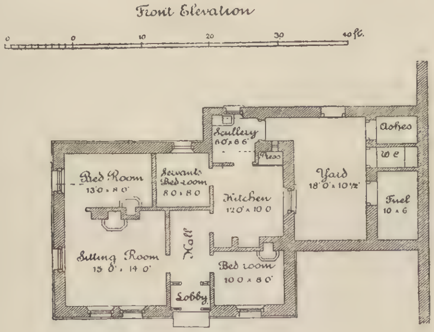


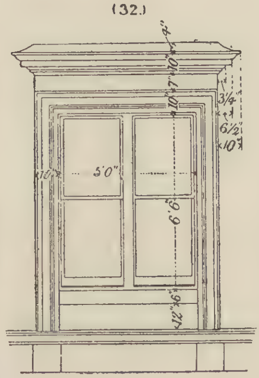
(63, 65, 70)

Front Elevation



Ground Plan.

(32)



Elevation of a Window.

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